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TITLE: The role of green innovation on oil and gas companies' financial performance

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Abstract

To comply with increasingly strict government environmental regulations, companies have to identify new and innovative solutions to make their products and processes greener, without compromising their financial objectives. This paper investigates the effect of green innovation on financial performance in the US and the European oil and gas industry using longitudinal data from 2010 to 2018. The analysis finds a diminishing positive effect on the financial performance for US companies, where the effect is positive at low levels of green innovation and turns negative at higher levels. For European companies, we find an increasing negative effect, where the effect is negative at low levels of green innovation and turns positive at higher levels. Moreover, we find that for European companies there is evidence that higher oil prices negatively moderate the relationship between disruptive green innovation and financial performance. This suggests that the opportunity cost of disruptive green innovation is high when the oil price is high and that companies are more willing to implement green innovation when the oil price is low. However, this moderating effect is not found for US companies. Based on these findings, as the effect of green innovation on the financial performance of European oil and gas companies depends on the level of companies innovation as well as oil prices, we suggest that in order to encourage oil and gas companies to invest more in green innovation, the public policy makers should have less strict environmental regulations and provide more policy support when the oil price is high. We also suggest that for the European oil and gas companies operating under very strict regulations, it is better to exert full effort in green innovation to gain financial profits. However, for the US companies operating under less strict environmental regulations, low to medium levels of green innovation practices would be more profitable.

Table of contents

Foreword

We want to thank our supervisor Niaz Bashiri Behmiri for all the help and guidance she has provided us while writing this thesis. She has been enthusiastic, engaging, supportive, and considerate throughout the whole process. Her dedication has exceeded our expectations and we have learned a lot during this period. We also want to thank the University of Stavanger business school for the opportunity to write this paper and providing us with all the necessary support.

1. Introduction

Green innovation has received increasing attention in recent years among governments, academics, and companies. Green innovation aims at reducing the negative impact on the environment and improve the environmental performance of companies through product and process innovation (Chen et al., 2006). With an increasing population, a highly developed economy, and increasing demand for energy, we are facing progressively severe global warming and climate change problems. The Paris Agreement (2015) signed by over 170 countries, set the target to limit the temperature increase to well below 2°C above pre-industrial levels by end of the century, aiming at reducing the risk of climate change (United Nations, 2015). Although the severity of the consequences of environmental pollution is widely known, progress is not promising. According to a recent report from the United Nations, the global average temperature has already achieved 1.1°C above the estimated pre-industrial averages (World Meteorological Organization, 2020). Greenhouse gas emissions are still increasing without any sign that the rate of emissions will decrease in the coming years (World Meteorological Organization, 2020). Green innovation can assist us to boost the speed at reducing emissions, thus continuous investment in new and innovative green technology is important.

Several studies have found that green innovation can bring important benefits to the company. Porter and Van der Linde (1995) pointed out that green innovation triggered by strict environmental regulations, improves the environmental performance and competitive advantage for the company, creating a win-win situation. Previous studies also indicate that green innovation can reduce the operational cost, enhance resource efficiency, strengthen supplier ties, improve product quality, bring competitive advantage, promote company image and increase customer loyalty (Kotabe & Murray, 1990; Shrivastava, 1995; Dangelico & Pujari, 2010; Cai & Li, 2018; Xie et al., 2019).

Palmer et al. (1995) challenged the win-win logic of Porter and Van der Linde and suggested that although investment in environmental management can improve the environmental performance, it is hard to prove the cost is well compensated from an economic perspective. Rennings (2000) argued that green innovation suffers from the "double externality problem". Green innovation creates technology knowledge externalities and environmental externalities during the innovation process (Rennings, 2000). Because of the market failure, the reward on the investment in green innovation for companies is less than their contribution to the social benefits (Rennings, 2000; Oltra, 2008). Consequently, many companies are reluctant and less motivated to take action in green practices.

Many previous papers have made efforts on finding the determinant factors which can spur green innovation practices. Papers have examined factors such as stringency of environmental policy, environmental subsidy, organizational capabilities, cultural differences, and stakeholders pressure with mixed results based on institutional theory, resource-based theory, and dynamic capabilities theory (see e.g., Porter & Van der Linde, 1995; Teece et al., 1997; Li, 2014; Weng et al., 2015; Huang & Li, 2017; Xie et al., 2019). Besides complying with regulations and showing social responsibility, one of the most important motivations for companies to invest in green innovation is whether the investment can create a win-win situation, to improve both environmental and the financial performance (Dangelico & Pujari, 2010). Previous studies indicate that drivers behind green innovation practices can be technology-push and cost-saving from the supply side, market-pull from the demand side, together with the influences from environmental policy (Horbach, 2008; Triguero et al.,2013).

With regards to the relationship between green innovation and companies' financial performance. There is no consensus among previous empirical studies' results. Some empirical results indicate that green innovation has a positive effect on company financial performance (see e.g., Shrivastava 1995; Li, 2014; Przychodzen & Przychodzen, 2015; Liao, 2018; De Azevedo Rezende et al., 2019). Others have found a negative relationship (Wally & Whitehead 1994; Crawford, 2008; Agulera-Caracuel & Ortiz-de-Mandojana 2013; Rexhäuser & Rammer, 2014), or no effect at all (Liao & Rice, 2010; Ghisetti & Rennings, 2014; Doran & Ryan , 2014).

Oil and gas are important energy resources, both presently and in the near future. It is estimated that fossil fuels contribute an important share to the increasing greenhouse gas emissions and oil and gas accounted for over 50% of the global CO_2 emissions from fuel consumption in 2017 (Ritchie & Roser, 2019). Thus, improvement within the oil and gas industry is very important for us to achieve environmental goals. In this thesis, we would like to study the relationship between green innovation and financial performance and extend the discussion of the relationship in the previous literature to companies within the oil and gas industry. Moreover, we wish to focus on the comparison between US and European oil and gas companies, which provides a more comprehensive understanding of the mechanisms for policy makers. The research questions are as following:

Research question 1: Does green innovation affect the financial performance of oil and gas companies in the US and in Europe?

Research question 2: As one of the most important financial indicators in the industry, does the crude oil price have a moderating effect on the relationship between green innovation and financial performance within oil and gas companies in the US and in Europe?

If we find evidence that green innovation can positively improve the companies' financial performance, the companies might have more confidence and less reluctance when investing in green innovation. We would also like to help policy makers to create more effective regulations and support systems. Thus, the environmental performance of a company can be improved while maintaining the desired financial performance.

In this paper, we use panel data collected from 2010 to 2018 from US and European oil and gas companies. For the US, we found a diminishing positive curvilinear relationship between green innovation and oil and gas companies' financial performance. This means that the investment made on green innovation is well rewarded when companies have low levels of green innovation; however, the effect turns negative at higher levels of green innovation. For Europe, we found an increasing negative curvilinear relationship. The result shows a negative effect at low levels of green innovation, and it turns positive at higher levels of green innovation. Therefore, European oil and gas companies should either not invest in green innovation at all or exert sufficient enough efforts to reach a certain point where they get a positive financial benefit. The different results from the two important regions provide evidence for policy makers to understand more about the influences of green innovation. We also found that the crude oil price has a negative moderating effect on the relationship between the disruptive green innovation and companies' financial performance in Europe, but the same effect is not present in the US result. This indicates that higher oil prices would discourage disruptive green innovation investment in European oil and gas companies, while lower oil prices are in favor of environmentally friendly decisions. We believe that the different results between the US and Europe come from two fundamental differences. First, the European countries follow stricter environmental regulations than the US as they put more emphasis on the priority of the environmental performances; therefore, it is harder for European oil and gas companies to achieve competitive advantage as a first-mover. Second, the US is self-sufficient while the

European countries depend heavily on oil and gas imports. The differences affect the motivations and profitability of the green innovation practices among oil and gas companies in these two regions.

Our study makes two main contributions to the current literature. First, we contribute to the innovation-firm performance literature. To the best of our knowledge, there is no previous study that examines the relationship between green innovation and companies' financial performance within the oil and gas industry. Second, our study contributes to the oil price-oil and gas companies' financial performance literature. We find that not only is oil price an important factor for these companies' financial performance, but it can also have a moderating effect on the green innovation-performance relationship in oil and gas companies.

The thesis is organized into seven sections. Section 2 provides a theoretical background and review of previous literature. Section 3 introduces the database and section 4 discusses the methodology and models of the study. Section 5 presents the empirical results. Section 6 provides an analysis and discussion of the results. Section 7 concludes our findings and provides suggestions for future studies.

2. Theoretical background and literature review

2.1 Innovation

Joseph Schumpeter is often assumed to be among the first who identified the importance of innovation (Rogers, 1998). He emphasized that the economy is developed through continuous innovation, which causes "creative destruction" as the new product substitute the old one (Śledzik, 2013). Innovation can be defined as the generation, implementation, and application of new ideas to products, processes, or services in a company's activities (Calantone et al., 2002; Rogers, 1998). Aiming to set a standard for collecting and interpreting innovation data, OECD[1] defines innovation as the "implementation of a new or significantly improved product (goods or services), or process, a new marketing method, or a new organizational method in business practices" (OECD, 2005). Unlike inventions that only need to convert new technology into a new product or process, innovation is concerned with the commercialization process and needs

[1] OECD: The Organization for Economic Co-operation and Development. It is an international economic organization, which aims to build better policies and international standard-setting (OECD, 2020).

to put the new product or process into practical use and introduce them to the market (Rogers, 1998; Rennings, 2000).

In today's highly competitive business environment, innovation is a useful tool for companies to adapt to the fast-changing technological environment and society (Gopalakrishnan, 2000). According to the resource-based view (RBV) in strategic management, the resources and competences the company possesses distinctively are the strategic capabilities specific for the company. Therefore, they are key factors for companies to achieve competitive advantage (Amores-Salvadó et al., 2014). The dynamic capabilities view (DCV) extends the RBV theory. In a rapidly changing technological environment, the competences to innovate timely and the capabilities to renew internal and external resources continuously, are important to ensure the sustainability of competitive advantage and financial performance (Teece et al., 1997). Innovation speed, quality, and magnitude are highly important factors to achieve successful innovation and influence companies' financial performance positively (Wang & Wang, 2012; Gopalakrishan, 2000).

Innovation is an important strategy for companies' daily operations and can bring many benefits. Innovation can make full use of resources, improve efficiency, increase intangible assets, satisfy customer needs, beat competitor threats, increase the potential value of the company, and increase the market share (Wang & Wang, 2012; Calantone et al., 2002). Ireland and Webb (2007) indicated that innovations are a means for companies to exploit current competitive advantages, to explore future opportunities, and help companies to achieve superior profitability.

Innovation is often separated into two categories of sustaining and disruptive. Sustaining innovation is the year by year exploitative improvements in existing technology, products, and processes, which makes out a company's improvement trajectory. Often, these are incremental improvements of capabilities, which are already established as valuable by the company (Bower & Christensen, 1995; March, 1991). According to Christensen and Raynor's theory of disruptive innovation, companies frequently focus too much on the existing customers' needs instead of looking for new market opportunities (Christensen & Raynor, 2013). By doing too much sustained innovation, the technology will overshoot the consumers' ability to use it and improvements become less impactful. For other companies, this provides an opportunity to enter the market and serve a new segment that has previously been ignored.

To stay competitive, companies need to adapt when technologies or markets change. It is vital for all companies to continuously expand their portfolio to avoid being disrupted by others in the long run. According to the Christensen Institute (2020), disruptive innovation can be described as “a process by which a product or service initially takes root in simple applications at the bottom of a market—typically by being less expensive and more accessible—and then relentlessly moves upmarket, eventually displacing established competitors. As seen in Figure 1, there are two important characteristics of disruptive innovation. First, the innovation is originally something which is not valued by the existing customer. Second, the performance increases at such a rate that it can later invade the established markets and lower the demand for the conventional product (Bower & Christensen, 1996).

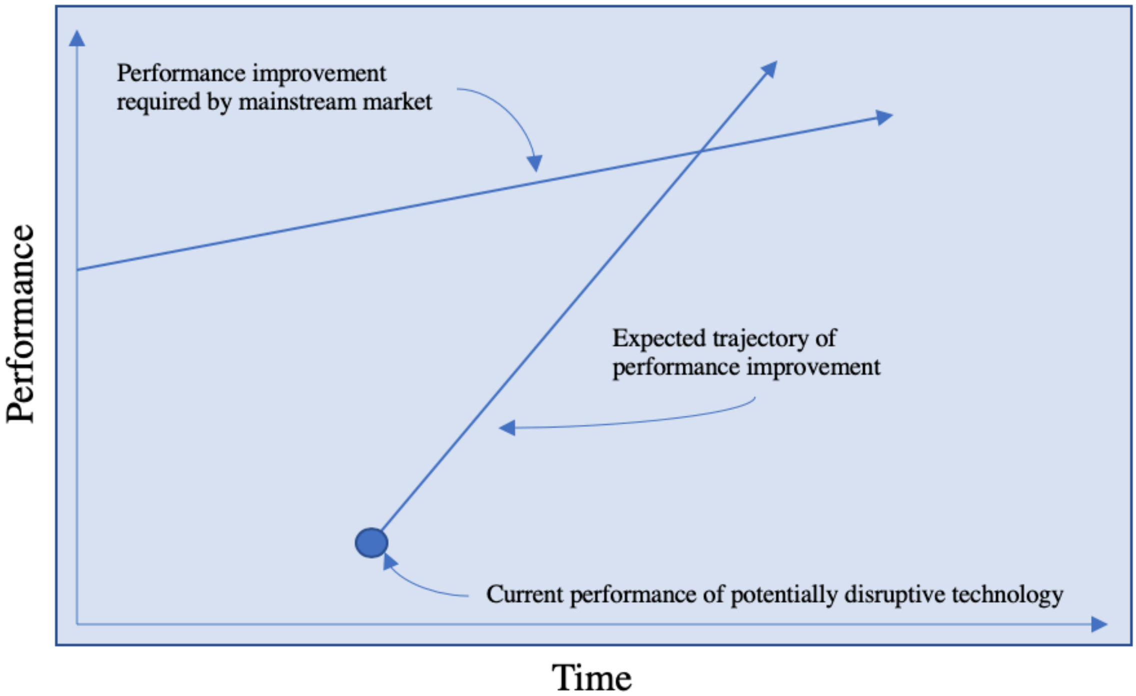

Figure 1: The disruptive innovation model (Bower & Christensen, 1996)

According to the theory, there is a possibility that a disruption within the oil and gas industry will come from outside the traditional oil and gas companies. Consequently, potential disruptive innovations are hard to detect, and the new disruptive innovations are expensive to explore when compared to sustaining exploitation of existing technology. However, challenging existing income streams is a necessity to stay profitable in the long run, as a company should rather be disrupted by itself. When a company allocates scarce recourses, they must be mindful of the fact that more investments in short-term improvements of existing technology might come at the cost of long-term financial performance (Uotila et al., 2009). Previous studies have found this trade-off has an inverse U-shape, where a balanced share between exploitative sustained investments, and explorative disruptive investments has the largest positive effect on the company financial performance (Uotila et al., 2009; Belderbos et al., 2010).

2.2 Green Innovation

Green innovation is a subgroup of general innovation and is interchangeable with terminologies such as "eco/ ecological innovation", "environmental innovation", and "sustainable innovation" (Küçükoğlu et al., 2015; Tietze et al., 2011). It is an innovation that concerns sustainable development in technology, social, and institutional changes (Rennings, 2000). According to Chen et al. (2006), green innovation can be defined as "hardware or software innovation that is related to green products or processes, including the innovation in technologies that are involved in energy-saving, pollution-prevention, waste recycling, green product designs, or corporate environmental management". Green innovation can be managed responsively or proactively (Bigliardi, 2012). Responsive innovations, which mainly are regulation-driven, create incremental changes but are often time-consuming and inefficient, while proactive innovations aim beyond environmental regulation standards to create systematic changes, which are often more efficient but need substantial financial support (Noci & Verganti, 1999; Bigliardi, 2012).

Green innovation produces many benefits. It can reduce negative environmental impact through the full life cycle of products, processes, services, and systems (Lin et al., 2019). It can also assist in building high entry barriers to other competitors and provides competitive advantages to the companies (Chang, 2011; Lin et al., 2019). However, with all advantages of implementing green innovation have for both companies and society, it is not easy to achieve. In this regard, Rennings (2000) stated that companies are inadequately motivated to invest in green innovation due to the "double externality problem". Since green innovation creates both technological and environmental externalities at the R&D phase and the diffusion phase respectively, policy makers must correct these market failures to motivate companies to invest in green innovation (Rennings, 2000; Popp et al., 2010). Only when sufficient financial support is provided through technological innovation policies and environmental externality costs are properly charged through environmental policies, can green innovation products compete with non-green products in a fair way (Rennings, 2000).

2.2.1 Green product innovation

Green innovation is often divided into green process innovation and green product innovation (Chen et al., 2006). Durif et al. (2010) defined green product innovation as "a product whose design and attributes (and/or production and/or strategy) uses recycling (renewable/toxic-free/biodegradable) resources, which improves environmental impact or reduces environmental toxic damage throughout its entire life cycle". Noci and Verganti (1999) pointed out that green product innovation requires an overview of the whole life cycle of the product. As shown in Figure 2, green product innovation focuses on three key factors: material-saving, energy-efficiency, and pollution-reduction, corresponding to the "different stages of product's physical life cycle-manufacturing process, product use, and disposal" (Dangelico and Pujari, 2010). Chen et al. (2006) stated that green product innovation has an impact on company image. Ar (2012) found that green product innovation has a significant positive effect on Turkish manufacturing companies' performance and enhances their competitive advantage. Lin et al. (2013) also found that green product innovation can help motorcycle companies in Vietnam gain sustainable development and achieve business targets. Green innovation plays an important role in assisting companies to position themselves in a dynamic market and business environment (Ar, 2012).

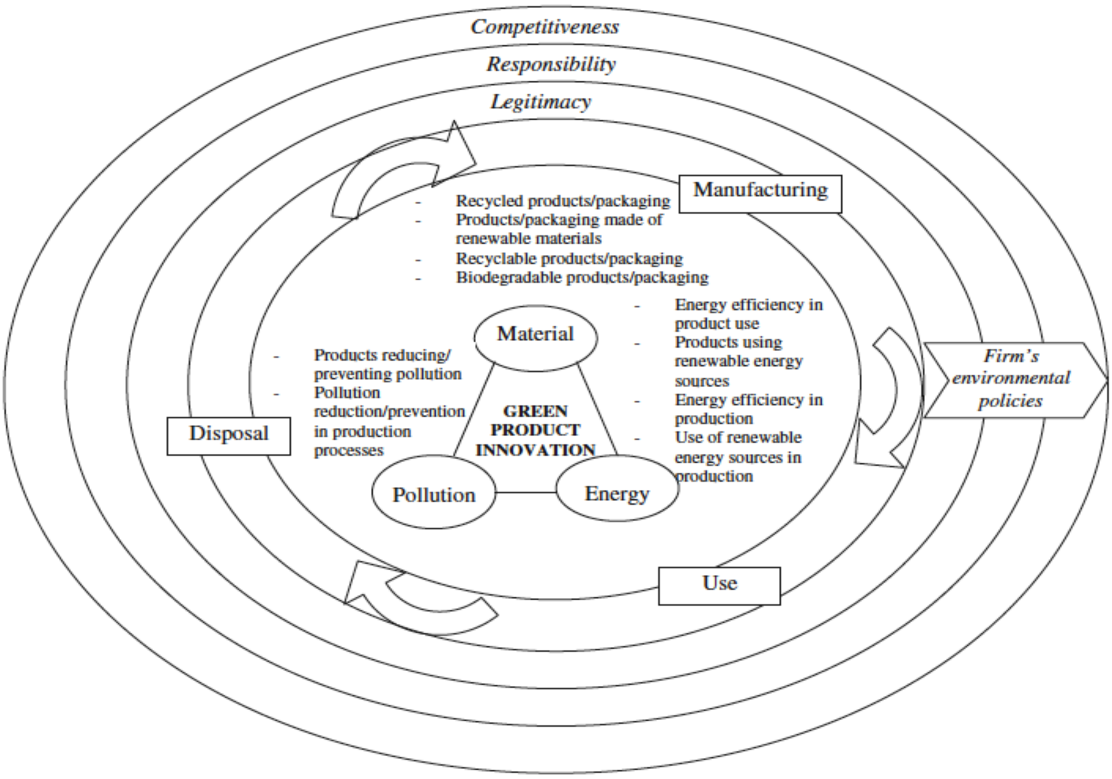

Figure 2: A conceptual framework for green product innovation(Dangelico & Pujari, 2010)

2.2.2 Green process innovation

Green process innovation includes reducing pollutions- air and water emissions, improving efficiency both in resources and energy use for producing products and introducing new clean energy types – such as switching from fossil fuels to bioenergy (Kivimaa & Kautto, 2010). Bigliardi and Dormio (2009) emphasized the importance of process innovation in achieving successful innovation, as it can assist the companies to enhance market share, improve product quality, and broaden the product assortments. To obtain a long-term sustainable competitive advantage, companies must focus on both product innovation and process innovation (Kotabe & Murray, 1990). Green process innovation, which "requires systematic improvements to the whole operational and managerial process" (Li et al., 2017), creates foundations for implementing green product innovations now and encouraging more of them in the future (Xie et al., 2019). However, an empirical study indicated that compared to green product innovation, many companies ignore green process innovation (Li et al., 2017). The reasons might be that process innovation typically improve internal efficiency and product quality, which are less noticeable by the customers (Gopalakrishnan et al., 1999). Also, it is much more costly for companies to implement green process innovation and it takes time to show any positive results (Li et al., 2017). Nevertheless, green process innovation is found to have a significant positive effect on green product innovation (Xie et al., 2019). In contrast to green product innovation that is more regulation-driven and market-driven from the external environment, green process innovation is driven from the inside of the company with the requirements to improve internal efficiency. As it is implicit, it could be more difficult for competitors to imitate (Ireland & Webb, 2007; Chen, 2010).

2.3 Oil and gas companies and green innovation

2.3.1 Oil and gas companies, emissions and the threat of global warming

The alarm bell of environmental problems and climate change has been ringing for years. The population growth, industrial development, and the use of fossil fuels are key drivers of the increasing anthropogenic greenhouse gas emissions, which contributes to global warming (IPIECA[2], 2020). Energy production and consumptions contribute a big portion of global environmental emissions, especially fossil fuels (United Nations, 2009). Fossil fuel usage

[2] IPIECA: International Petroleum Industry Environmental Conversation Association, founded in 1974. It is a global non-profit oil and gas industry association and the primary communication channel between the global oil and gas industry and the United Nations on environmental, and social issues. (IPIECA, n.d.)

accounts for more than 90% of greenhouse gas emissions and mainly occurs in the downstream. However, emissions from upstream oil and gas companies have an important role both for life cycle emissions of fossil fuels and for the fossil fuel exporting countries (Gavenas et al., 2015). As Figure 3 shows, oil and gas contributed over 50% of global fuel CO_2 emissions in 2017.

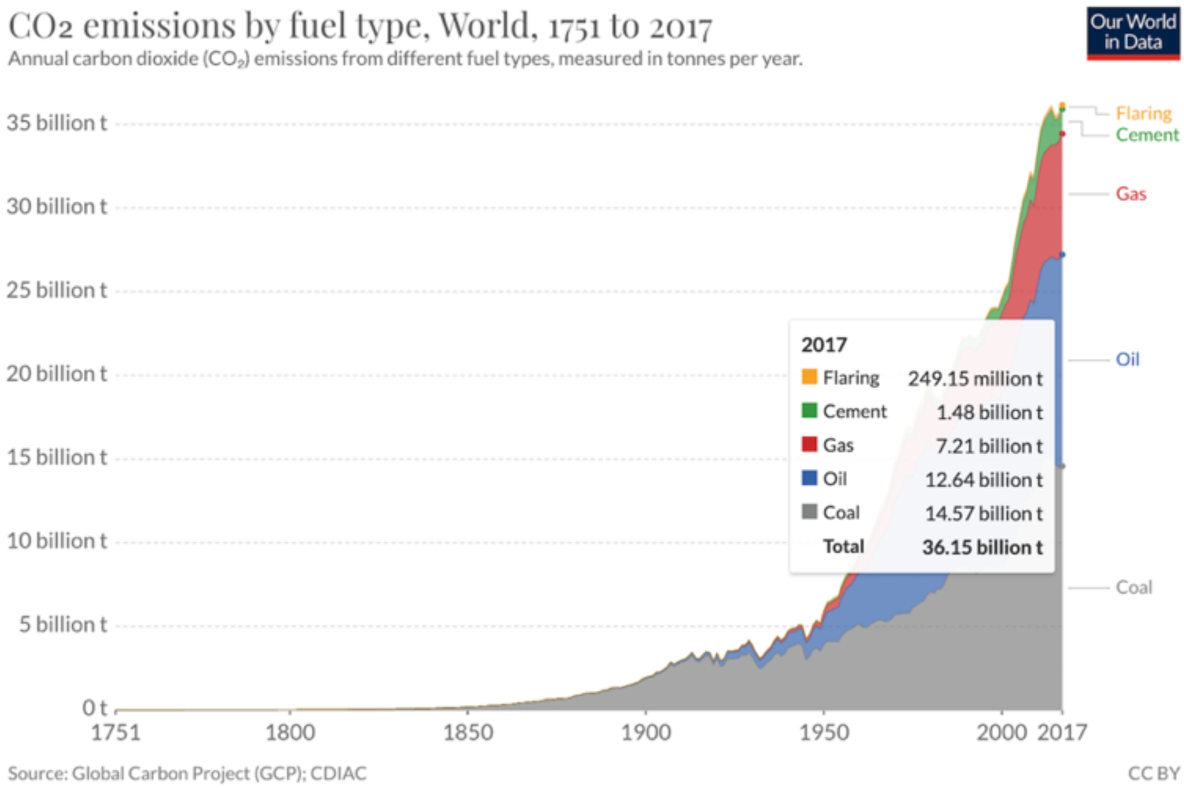

Figure 3: World CO_2 emissions by fuel type, 1751-2017 (Ritchie & Roser, 2017)

Despite the background of energy transition and high-speed growth development of renewables, oil and gas will still play an important role in energy systems in the near future. Oil and gas accounted for over 50% of the global energy consumption in 2018 (see Figure 4). Considering this, green innovation and the effort made to reduce the greenhouse gas emissions within oil and gas companies would have significant positive impacts on the environment and they are vitally important in enabling us to achieve the climate change target.

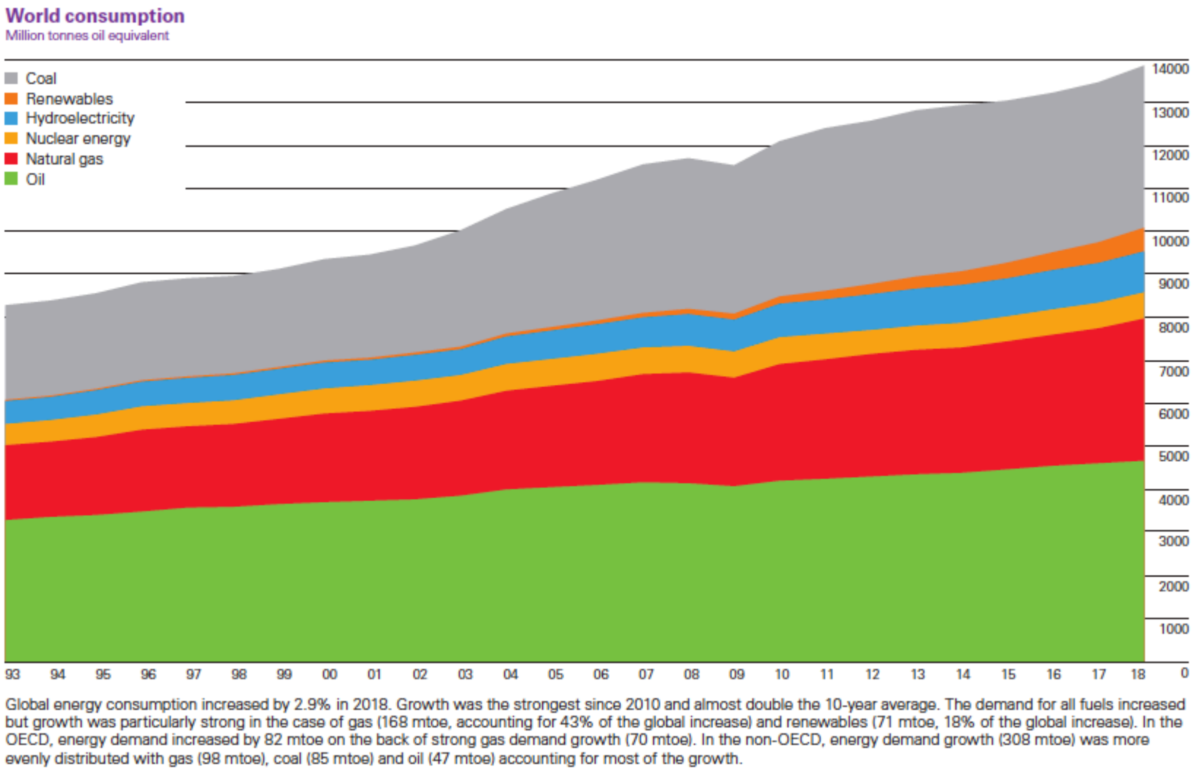

Figure 4: Global Energy Consumption 1993-2018 (BP, 2019)

To strengthen the actions toward climate change, the Paris Agreement on climate change set the target as "holding the increase in the global average temperature to well below 2°C above pre-industrial levels and pursuing efforts to limit the temperature increase to 1.5°C above pre-industrial levels" through the implementation of national greenhouse gas emissions reduction plans (United Nations, 2015). However, the BP Statistical Review of World Energy report states that during the year 2018, the primary energy consumption and greenhouse gas emissions grew at the fastest rates since 2010 (BP, 2019). The progress for carbon emission is contradicting what the Paris Agreement requires (BP, 2019). With the increasingly severe climate change problems, there is no doubt that oil and gas companies will face much stricter environmental regulations domestically and internationally. Like it or not, it is the oil and gas companies' task to follow such regulations and the initiatives for technology development and green innovations are strongly needed.

Oil and gas companies are also facing increasing pressure from environmental-conscious investors and shareholders. The decision-making on oil and gas projects is always complicated since the investment amount is high and the pay-back time is long. With the uncertainties of carbon tax and stricter environmental regulations, the investors could be concerned that investment in oil and gas assets will become stranded, let alone the projects which are already ongoing. Thus, oil and gas companies need to find solutions to reduce carbon footprints and remain sustainable in the energy market (Shojaeddini et al., 2019). To eliminate investors' concerns and meet the requirement for environmental-friendly oil and gas production, green innovation is an important investment strategy to be considered.

Facing pressure from the public, more stringent environmental regulations, and environmental-concerned investors, oil and gas companies have already started to take action. They try to utilize new technologies to reduce greenhouse gas emissions in oil and gas productions. Major international oil companies (IOCs) Equinor, together with Shell and Total, are trying to develop CCUS (Carbon capture, utilization, and storage) technology to achieve low-carbon production targets under a project called Northern Lights (Equinor, 2019). Shell has utilized optical gas imaging (OGI) cameras to monitor and detect methane emissions[3] in gas production (Royal Dutch Shell, n.d.). AkerBP is the first company on the Norwegian Continental Shelf to set up an onshore remote-control room to manage the operation on offshore field Ivar Aasen in the North Sea (AkerBP, 2019). Also, artificial intelligence (AI) technologies are increasingly utilized within the oil and gas industry, which would help to reduce greenhouse gas emissions during the operation process and improve work-efficiency (Equinor, 2020).

2.3.2 Green innovation and oil and gas companies' financial performance

Green innovation can affect the financial performance of oil and gas companies through three complementary mechanisms.

The first channel is through a differentiation strategy. Not all products produce greenhouse gas emissions at every stage of the product's life cycle; however, oil and gas are exceptions. They have a significant environmental impact during the full life cycle, from production, use to disposal. Thus, significant product differentiation and competitiveness can be drawn from radical green product innovation from material selection, energy use, or pollution prevention (Dangelico & Pujari, 2010). Reducing pollution and creating more environmental-friendly products from green product innovation can increase the demand among environmentally conscious customers (Aguilera-Caracuel & Ortiz-de-Mandojana, 2013). The tangible new product or services assist the company in reaching new markets and face less competition (Chen,

[3] Methane is a potent greenhouse gas, which is contained in natural gas and it is assumed to have a stronger warming effect than CO_2 (Royal Dutch Shell, n.d.).

2008). The differentiation strategy enables the company to charge a higher premium for the product and enables higher profit.

The second channel is through the cost strategy. Green innovation which aims at preventing pollution, improving energy efficiency, and reducing resource consumptions, leads to cost reduction by avoiding waste in raw materials, reducing environmental cost, and improving productivity (Dai & Zhang, 2017). Moreover, with the increasing possibility of CO_2 emission tax, companies who produce environmental-friendly products face lower tax rates than other companies, which enhances the cost leadership in a sustainable way.

The third channel is through green image. Green image can act as a "signal of a company's environmental commitment towards its key stakeholders (Amores-Salvadó et al., 2014)" and it involves how those key stakeholders perceive the company's environmental characteristics (Xie et al., 2019). There is a consensus between governments, investors, and customers that the traditional fossil fuel companies should shoulder the responsibilities for reductions in greenhouse gas emissions. For environmentally sensitive industries such as oil and gas production, creating a positive corporate image in the minds of key stakeholders can be crucial to operate successfully (Amores-Salvadó et al., 2014). Efforts made on green innovation could be an important external communication channel to strengthen the company's green image, which can bring several benefits (Saha & Darnton, 2005). On one hand, green image reduces the possibility of environmental protests and penalties, to reduce the operation cost. On the other hand, it generates a positive public corporate reputation for the company, which can increase customer satisfaction, brand loyalty, and influence consumer purchase decisions (Chen, 2010; Chang & Fong, 2010). Green image has also been proven to have a significant positive effect on the company's financial performance and can moderate the relationship between green product innovation and company financial performance (Amores-Salvadó et al., 2014; Xie et al., 2019).

2.4 Literature review

Several previous studies have examined the relationship between green innovation and company financial performance; however, it seems that there is little consensus on the relationship.

Extensive empirical studies have shown that green innovation can generate a positive effect on companies' performance. Li (2014) used a survey method to investigate 148 manufacturing firms in China. The estimation results indicated that green innovation has a significant positive effect on environmental performance, and it has a positive effect on financial performance through the mediating role of environmental performance. The paper also found that pressure from the government, oversea customers, and competitors are the main drivers for these firms to implement green innovation practices. Lee and Min (2015) used panel data over ten years on a sample of around a thousand Japanese manufacturing firms. By using regression analysis, they found that the investment in green innovation (Green R&D) would effectively reduce the carbon emission and improve the financial performance of the company. Przychodzen and Przychodzen (2015) pointed out that eco-innovative companies have higher returns on asset and equity by studying publicly traded companies in Poland and Hungary. They argue that companies which are investing in green innovation will perform better due to attracting green rents in the market. Huang and Li (2017) researched green innovation and companies' financial performance by utilizing a questionnaire survey analysis. They found that both green product innovation and green process innovation positively affect the companies' financial performance in the information and communication technology industry in Taiwan. By utilizing a structural equation modeling method, Liao (2018) used a survey analysis and found that green innovation, including green organizational innovation, green process innovation, and green product innovation, positively affect the companies' financial performance. The empirical study utilized a sample of 366 manufacturing companies via a survey in China and indicated that different types of culture, such as clan culture, adhocracy culture, and market culture, play important role in promoting green innovation within companies. Lin et al. (2019) applied a Generalized Method of Moment (GMM) approach and found that green innovation positively affects financial performance in the automotive sector. The paper also found that the small-sized companies achieved a higher return from green innovation than large-sized companies. De Azevedo Rezende et al. (2019) performed an analysis on the sample data of 356 multinational companies by using a fixed effects panel regression. The results showed that green innovation has a positive effect on financial performance on a time-lag basis (1-3 years). The study also indicated that the internationalization level has no mediating effect on green innovation on financial performance. Xie et al. (2019) used a content analysis method and concluded that both green process innovation and green product innovation can improve a company's financial performance in heavily polluting Chinese manufacturing industries. They also found that the green product innovation moderates the relationship between green process innovation and financial performance, and the green image mediates the relationship between green product innovation and financial performance.

However, innovation can also lead to a negative effect on companies' financial performance. Wally and Whitehead (1994) argued that the "win-win" logic of the green practices on environmental and financial performance is questionable. Especially when relatively easy environmental problems have already been solved, while the remaining ones are too expensive to touch. For industries facing fierce competition and low margins, it is hard to persuade shareholders to allocate resources on green innovation with uncertain returns (Wally & Whitehead 1994). Due to the complexity and risk during the innovation process, companies that allocate resources to make innovation efforts may gain nothing but increased operation costs (de Oliveira et al., 2018). Agulera-Caracuel and Ortiz-de-Mandojana (2013) compared green innovative companies and non-green innovative companies globally by using matched-pairs analysis and found that green innovative companies do not have better financial performance than their counterparts. However, when examining within the group of innovative companies, they found the intensity of green innovation to be positively related to company profitability. Forsman et al. (2013) made a case study based on five companies that achieved superior competitiveness and five firms that lost their competitiveness during the process of pursuing green innovation practices. The study found that companies who have little control on cost-efficiency, low level of the customer relationship, and low capability of responding to declining competitiveness usually result in unsuccessful eco-innovators. Rexhäuser and Rammer (2014) performed a study on sample data from the German part of the Community Innovation Survey. They found that if green innovation only improves environmental performance without simultaneously improving resource efficiency, the company's financial performance will not be improved.

Some previous studies indicate that green innovation does not affect companies' financial performance at all. Amores-Salvadó et al. (2014) found no direct impact of environmental product innovation on the company financial performance, using survey data collected from Spanish metal companies. Although by using linear regression, the authors found that green image can positively affect company performance and the green image has a moderating effect between environmental product innovation and company financial performance. Ghisetti and Rennings (2014) performed a study based on a panel data of German companies from all sectors, which showed no significant effect of environmental innovation on financial performance.

However, when separating the term "environmental innovation" into two categories of "energy and resource efficiency innovation" and "externally reducing innovations", they found that energy and resource efficiency innovation has a significant positive effect on profitability. On the contrary, the externally reducing innovation has a significant and negative effect on profitability, especially when introduced as a response to incentives. Doran and Ryan (2014) made an empirical study using a survey sample of 2181 firms in Ireland. The paper divided eco-innovation in to nine types, where six types were found to have insignificant effects on companies' financial performance. De Oliveira et al. (2018) indicated that innovation efforts have a significant positive effect on promoting new products. However, the new product does not result in positive financial performance. To investigate this relationship, the authors use exploratory factor analysis and structural equation modeling to analyze two nationwide surveys, which include 5025 companies in Brazil. Liao and Rice (2010) concluded that there is no direct effect of innovation on financial performance by studying the panel data of a survey among Australian manufacturing SMEs. However, the indirect effect of innovation mediated by market engagement on financial performance exists by employing Structural Equation Modeling. This draws the importance of rearrangement of operational activities along with innovation to promote the company's performance.

To the best of our knowledge, most previous studies examine the effect of green innovation on financial performance in industries from the demand side of oil and gas, such as the metal and automotive industry. There is no previous study that examines the effect of green innovation on financial performance from the supply side of oil and gas, which are oil and gas companies. In this study, we aim to fill this gap and focus on US and European based oil and gas companies. As the literature is inconclusive, we develop the subsequent hypothesis:
Hypothesis 1: Green innovation has an effect on the financial performance of US and European oil and gas companies.

According to the recourse-based view, companies that utilize their capabilities most innovatively will gain more unique knowledge and higher competitive advantage. Thus, the accumulation of knowledge and resources might imply an increasing return to scales as they become harder for competitors to copy, resulting in a curvilinear relationship on financial performance (Hart, 1995). Also taking into consideration that too much innovation investment might affect other operational activities by hugging too many resources, the relationship is expected to have an inverted U-shape (Wagner, 2005). Bontis et al. (2005) explored the relationship between innovation capital (R&D intensity) and financial performance (ROA). The analysis used data on 297 companies from a 2003 survey conducted on the 1000 largest companies in Taiwan. By using OLS regression analysis, they identified an inverted U-shape relationship between innovation capital and financial performance. The study found that the optimal amount for research and development (R&D) investments is 6.39% of the total sales revenue and that over investing in innovation will have a negative impact on the company's financial returns.

This result has also been explored in the environmental performance literature where researches have tried to identify the characteristics of the relationship between green performance measures and financial performance. In this regard, Misani and Pogutz (2015) identified that companies' environmental outcomes, which capture their impact on the natural environment, have a curvilinear inverted U-shape relationship on the Tobin's q. Using a panel data sample of 127 global companies in carbon-intensive industries, they performed an OLS regression analysis including a squared term for environmental outcomes. They also found that green process performance has a positive moderating effect on the relationship between carbon emissions and Tobin's q. Their findings suggest that companies investing in both reducing their carbon footprints and sustained green process innovations are rewarded with a better financial result. Ramanathan (2018) confirmed these curvilinear findings in a study that applied cross-sectional data from 134 UK manufacturing companies. The OLS regression results show positive effects from both the environmental performance variable and the squared term of it on companies' financial performance. This suggests the relationship is positive and nonlinear, where higher environmental performance has an increasing return to scale on financial performance.

Innovation can also be an activity with high risk, especially for new or disruptive product innovation, where companies historically have reported a high rate of failure (Crawford, 2008). This might suggest that if companies are to be successful, they will have to invest sufficient funds in their innovation activities to gain financial benefits, implying a U-shaped relationship (Tidd & Bessant, 2018). Trumpp and Guenther (2017) identified such a curvilinear U-shaped relationship between corporate environmental performance (including measures for waste and carbon reduction) and corporate financial performance (ROA). They performed a one-way clustered panel OLS regression on a data sample of 696 international service and manufacturing companies. The results of a negative key variable and a positive squared variable argue that there has to be a minimum level of commitment before the relationship between environmental performance and financial performance becomes positive. However, there is little evidence from other empirical studies supporting this claim.

In this study, we will explore the curvilinear relationship between green innovation and financial performance in the US and European oil and gas companies. Therefore, we develop the following hypothesis:
Hypothesis 2: Green innovation has a curvilinear effect on the financial performance of US and European oil and gas companies.

As indicated by the previous section, the results of studies on the effect between green innovation and companies' financial performance are mixed. This makes us wonder if there is any other factor that moderates this effect? For the oil and gas industry, the crude oil price is the "elephant in the room". The oil price has important effects on oil and gas companies' financial performance. Boyer and Filion (2007) found a significant positive relationship between oil price and stock returns of oil and gas companies during the years 1995-1998 by using multifactor models in Canada. Dayanandan and Donker (2011) used generalized method of moments (GMM) to examine a sample of oil and gas companies from 1990 to 2008 in North America and found that the oil price significantly and positively affects the financial performance of oil and gas companies.

Also, the oil price is an important indicator of the macroeconomy. As one of the most important sources for energy in the world, Sek et al. (2015) pointed out that oil is a key direct input for production. Thus, the price of oil can affect economic performance through increasing production costs, promoting higher inflation, transferring wealth between oil producers and consumers, and through the changing exchange rates (Sek et al., 2015; Dayanandan & Donker, 2011). The same logic applies to oil-exporting and importing countries. Rassenfoss and Henni (2015) found that the negative oil price shocks have a big effect not only for the individual oil and gas companies but the whole national economy of oil-producing countries such as Malaysia.

Crude oil price is an important factor for the valuation of projects within oil and gas companies. It would therefore also affect the decisions in green innovation investment within the oil and gas companies. Higher oil price provides a cushion for the companies to take the risk on investments in (green) innovation. Low oil prices and the high growth rate of alternative energy

development might urge the oil and gas companies to make a change and innovate to survive by increasing production efficiency, reducing cost, and meeting the long-term energy demand (Rassenfoss & Henni, 2015). Under the threat of climate change and stricter environmental regulations, the requirement for such green innovation is more urgent. Oil and gas companies make strategic investments in green innovation aiming at surviving and sustaining in the long-term. We would like to see whether the oil price has any effect on the relationship between green innovation and the US and European oil and gas companies' financial performance. We present the following hypothesis:
Hypothesis 3: Crude oil price has a moderating effect on the relationship between green innovation and the financial performance of US and European oil and gas companies.

3. Data

3.1 Data collection and samples

The company data applied in this paper is collected from the DataStream database[4]. Moreover, the oil prices are collected from the US Energy Information Administration (the EIA). Due to the use of a credible secondary data source, it is implied that the selection of companies in the sample is random and we avoid the issue of sample selection bias.

For the panel data, we have four sample selection criteria. This is performed to remove companies with inaccurate or incomplete data from the sample. First, companies must belong to the oil and gas industry group according to the Thomson Reuters Business Classification (TRBC) industry group classification. This includes companies in the industries of integrated oil and gas, oil and gas exploration and production, and oil and gas refining and marketing. The companies in the database are continuously reviewed to include important events such as major developments, mergers, and acquisitions (Refinitiv, n.d.). Second, companies must have their headquarters in either the US or the European region. Third, companies must have a reported ESG[5] environmental pillar scores and innovation scores for the time period of this study. Finally, the period of interest is from 2010-2018. Companies with no reported data or several

[4] DataStream is considered one of the world's leading databases for financial time series data and enables analysis of several relationships of interest for our research question. In addition to utilizing resources from both national and intentional institutions and organizations, they also consider information from primary sources such as company reports and news articles to report data free from bias (Refinitiv, n.d.).

[5] Environmental, Social and Governance

missing values from the period will be excluded from the analysis to avoid the issue of an unbalanced dataset.

When introducing the fourth sample selection criteria, we understand that this might lead to an issue of survivorship bias in the sample. By excluding companies with missing values, we might miss out on important data, which can affect the result in a positive or negative direction. Omitting a company that has invested significantly into green innovation and gained a relatively poor financial result, might introduce a positive bias into the study. On the contrary, omitting a younger company with large green innovation budgets and good financial performance might negatively affect the study (Brown et al., 1992). However, by having an unbalanced sample, there might be an issue of correlation between the idiosyncratic error and the attrition, which will result in biased estimators. If companies were to drop out of the sample after a specific period, the data sample from the succeeding period is not likely to be random (Wooldridge, 2016). Due to not knowing whether the attrition is related to the idiosyncratic error or the time-invariant component, we have chosen to not include them in the sample.

3.2 Definitions of variables

In this sub-section, we present the selection of variables included in the study. The dependent and key variables are selected based on the theoretical background and main hypotheses. Control variables are based on findings from previous literature. All variables are reported in US dollars to keep the measurements uniform.

3.2.1 Dependent variable

We use the return on assets (ROA) as the dependent variable, which is a profitability ratio reported as an annual profitability statistic. In previous literature, ROA is widely used as a measure of companies' financial performance (Lin et al., 2019; Przychodzen & Przychodzen 2015; De Azevedo Rezende, 2019; Xie et al., 2019). Since oil and gas companies are generally capital intensive, ROA is more appropriate as a profitability measure compared to for example return on equity, because it shows how assets or resources are used to generate income as opposed to investments (Merrow, 2012). In the DataStream sample, ROA is calculated by:

$$ROA = \frac{(Net\ income - \ Bottom\ line + \big((Interest\ expense\ on\ debt - Interest\ capitalized)\ \times (1 - Tax\ rate)\big))}{Average\ of\ last\ years\ and\ current\ years\ total\ assets \times 100}$$

3.2.2 Green innovation variables

For the green innovation variables, we use longitudinal data of Environmental, Social, and Governance (ESG) scores from 2010-2018. The ESG data is collected and refined by over 150 research analysts from various sources such as annual reports, NGOs and company websites, news, stock and exchange filings, and CSR reports[6] (Refinitiv, 2020). The content is reviewed several times to assure representative and comparable results across all industries and companies. The ESG data consists of three pillar scores: Environmental, Social, and Governance. For this study, only the environmental pillar is of interest, which again consists of three different categories: Emission, Innovation, and Resource use. Table 1 shows an overview of the environmental pillar score with categories, themes, data points, and weight method.

Table 1: Overview of environmental pillar score categories (Refinitiv, 2020)

Pillars	Catagories	Themes	Data points	Weight method
Environmental	Emmission	Emissions	TR.AnalyticCO2	Quant Industry median
		Waste	TR.AnalyticTotalWaste	Quant Industry median
		Biodiversity *		
		Environmental Management Systems *		
	Innovation	Product Innovation	TR.EnvProducts	Transparency weights
		Green Revenues/R&D/Capex	TR.AnalyticEnvRD	Quant Industry median
	Resource Use	Water	TR.AnalyticWaterUse	Quant Industry median
		Energy	TR.AnalyticEnergyUse	Quant Industry median
		Sustainable Packaging *		
		Environmental Supply Chain *		

To answer the hypotheses, each analysis will be performed twice. First with environmental innovation score as the key variable, which will be used to measure disruptive green innovation (DGI). Secondly, with the environmental pillar score as the key variable, which will be used to measure a company's total green innovation (TGI).

a) *Environmental pillar score/ Total green innovation (TGI)*

TGI contains the categories of emission, resource use, and innovation. This is used as a key variable to capture both the sustained and disruptive innovation efforts of companies and includes measures for both product and process innovation. Emission measures the commitment and effectiveness towards reducing environmental emissions in the production and operational processes. Resource use measures performance and capacity to reduce the use of

[6] Corporate Social Responsibility reports.

materials, energy, or water, and to find more eco-efficient solutions by improving supply chain management. Innovation measures a company's capacity to reduce environmental costs and burdens for its customers, thereby creating new market opportunities through new environmental technologies and processes or eco-designed products. To calculate the final pillar score, the three categories are weighted in terms of relative importance for the industry group on a scale of 1-10. (Refinitiv, 2020)

b) Environmental innovation score/Disruptive green innovation (DGI)

DGI measures the green disruptive product and process innovation, which is characterized by the introduction of new market opportunities (Christensen & Raynor, 2013). The company score is a percentile rank scoring where companies are benchmarked within the same TRBC[7] industry group, based on different data points within the category (see Table 1). After values are determined, the company percentile scores within each data point are calculated from three different factors:

$$score = \frac{number\ of\ companies\ with\ worse\ value + (number\ of\ companies\ with\ the\ same\ value/2)}{number\ of\ companies\ with\ a\ value}$$

In both analyses, the variables for TGI and DGI will be included with a one-year lag. This is to make sure the benefits, as well as the costs of the investment, are taken into account as the short-term benefits might not be apparent.

3.2.3 Control variables

Several control variables, which previously have shown an effect on companies' financial performance, are included in the model.

Company size has shown an important impact on corporate financial performance as it affects the company's capital structure (Kurshev & Strebulaev, 2015). In general, studies have found a positive impact of size on performance as larger companies might be in the position to benefit from economies of scale, which would lower the cost of large-scale production (Miller, 1978; Xie et al., 2019). However, some studies have also found that small-sized businesses have higher investment returns than those of a larger size, which results in a negative relationship (Bagirov & Mateus, 2019; Lin et al., 2019). In this study, the natural logarithm of total assets

[7] Thomson Reuters Business Classification industry group classification.

will be used to measure company size, as in line with previous literature (Bagirov & Mateus, 2019; Xie et al., 2019). The variable will be included with a one-year lag to avoid the simultaneity issue where the financial performance might be estimated to affect the size.

Leverage ratio/Gearing is measured as the percentage ratio of total debt to total capital and is included to account for the company risk level. A high leverage ratio indicates that the company's profitability might be lowered due to debt interest, while a low ratio might signify risk-averse attitudes or tight operating margins (Haniffa & Hudaib, 2006). In previous literature from various industries, including oil and gas, there is no consensus about the direction of the leverage ratios effect on financial performance (Bagirov & Mateus, 2019; Lin et al, 2019: Weir & McKnight, 2002). The variable is included with a one-year lag as the leverage ratio's effect is usually lagged (González, 2013).

Oil price is one of the central drivers for financial performance in oil and gas companies, as the components of revenue are based on product price and quantity of sales (Bagirov & Mateus, 2019). The price effect on revenue is expected to be even stronger in the oil and gas industry because commodity price is the main explanatory element when measuring performance in resource-based industries (Dayanandan & Donker, 2011). Since this study is divided based on regions, two different benchmark oil prices will be used depending on the region of residence. The control variable used for the US region is the logarithm of West Texas Intermediate (WTI) Cushing Oklahoma crude oil price, obtained as the annual average price in dollar per barrel. For the European region, the oil price is the logarithm of Brent crude price, obtained as the annual average price in dollars per barrel.

A *Dummy variable* for the 2014-2015 oil crisis is included in the model. As the oil price has a significant effect on financial performance in oil and gas companies, we also expect a major drop in the price to have a negative impact in the respective years. The variable takes the value of 1 for the years 2014 and 2015 and 0 otherwise.

3.2.4 Nonlinear components

To get a better insight into how green innovation affects the financial performance of companies in the oil and gas industry, the analysis is expanded with additional variables to try and capture the curvilinear effects and moderating characteristics of the key variables. First, we introduce the quadratic terms of the green innovation variables. This is so we can see if there is evidence of any curvilinearity, how this relationship is shaped, and where the hypothetical turning point is located. We are especially interested in DGI, as evidence from previous research shows a curvilinear relationship between disruptive innovation activities and financial performance (Uotila et al., 2009; Belderbos et al., 2010). Second, to explore the hypothesis of a possible moderating effect of oil price on the relationship between green innovation and companies' financial performance, an interaction term of the green innovation variables and oil price is included.

3.3 Descriptive statistics and correlation coefficients

For the US companies, the sample consists of 243 total observations divided by 27 companies over 9 years. For Europe, we have 153 total observations divided by 17 companies over 9 years. All observations are from 2010-2018. The data is considered a short and balanced panel data due to few time periods and many individuals where $T_i = T \textit{ for all } i$.

Table 2: US Descriptive statistics

US Descriptive Statistics[8]		Mean	Std. Dev.	Min	Max		
ROA	overall	1.320	15.716	-119.83	59.53	N	243
	between		4.047	-8.248	8.507	n	27
	within		15.204	-110.262	59.397	T	9
$log(size)$	overall	16.450	1.484	13.342	19.672	N	243
	between		1.349	14.347	19.585	n	27
	within		.396	14.931	17.431	T	9
$Leverage$	overall	43.914	64.127	0	851.62	N	243
	between		39.529	12.569	227.437	n	27
	within		51.004	-129.103	668.097	T	9
$log(oil\ price)$ (WTI)	overall	4.261	.310	3.768	4.585	N	243
	between		0	4.261	4.261	n	27
	within		.310	3.768	4.585	T	9
DGI	overall	47.959	19.851	36.43	96.77	N	242
	between		18.422	38.87	95.853	n	27
	within		8.056	-1.205	84.660	T	8.96
TGI	overall	51.128	22.854	17.63	97.01	N	242
	between		21.851	24.422	93.177	n	27
	within		7.535	30.480	72.202	T	8.96

[8] Std.Dev is the standard deviation. Between is the difference between the individual companies in the sample, regardless of time period. Within is the difference across time within the companies in the sample. Overall is the combined Between and Within difference.

Table 3: Europe Descriptive statistics

Europe descriptive Statistics[9]		Mean	Std. Dev.	Min	Max		
ROA	overall	2.654	10.205	-41.69	62.7	N	153
	between		2.665	-4.294	7.18	n	17
	within		9.870	-39.098	65.292	T	9
$log(size)$	overall	16.448	2.084	12.192	19.869	N	153
	between		2.127	12.852	19.662	n	17
	within		.236	15.706	17.192	T	9
$Leverage$	overall	31.455	20.336	0	114.11	N	153
	between		16.629	3.32	63.466	n	17
	within		12.312	-15.801	82.099	T	9
$log(oil\ price)$ $(Brent)$	overall	4.342	.344	3.776	4.715	N	153
	between		0	4.342	4.342	n	17
	within		.344	3.776	4.715	T	9
DGI	overall	60.852	26.932	.18	99.71	N	153
	between		25.927	34.573	95.507	n	17
	within		9.408	-.406	84.844	T	9
TGI	overall	69.071	19.926	20.02	97.38	N	153
	between		19.205	32.963	94.224	n	17
	within		6.902	43.390	82.510	T	9

[9] Std.Dev is the standard deviation. Between is the difference between the individual companies in the sample, regardless of time period. Within is the difference across time within the companies in the sample. Overall is the combined Between and Within difference.

Tables 2 and 3 report the descriptive statistics of the US and the European data samples respectively. We see that there are no time-invariant variables in the model, as there is no within variation of the standard deviation equal to 0. The mean values of ROA for US and European companies are 1.320 and 2.654 with standard deviations of 15.716 and 10.205 respectively. Thus, the profitability ratios for US companies are a little more volatile than for European companies. We see that the maximum value for ROA of the two regions is relatively similar with a value of around 60. However, the minimum value for US companies is -119.83 and is considerably lower than the European companies' minimum of -41.69. The standard deviation of ROA for US companies is also higher. This indicates that the mean value for US companies is subject to an outlier. The within variation of the standard deviation is higher than the between variation for both the US and the European region, which means there is higher variation across time than between individuals. This is often the case for profitability measures of companies operating in open economies, as they are subject to variation in the business cycles (Sørensen & Whitta-Jacobsen, 2010).

From the descriptive data, we see that European companies have a higher mean value of DGI and TGI compared to the US. An interesting observation is that for both scores in the US and the European data, the between variations of the standard deviations are higher than the within variation, which means more variation across companies than over time. Looking at DGI, we see that the European region has a wider range of scores with a higher overall standard deviation than the US. This can be a result of countries within Europe having different policy measures and incentives for disruptive green innovation compared to the US, where policy measures are more uniform (Ghisetti & Rennings, 2014). This is supported by the higher value of between variation in the standard deviation for European companies compared to US companies.

Next, we report the correlation coefficient matrix and Variance Inflation Factor (VIF) test results for the US and the European data samples in Tables 4 and 5 respectively.

Table 4a: US correlation matrix

US correlation	1	2	3	4	5	6
1. ROA	1.000					
2. $log(size)$	0.020	1.000				
3. $Leverage$	0.050	-0.320***	1.000			
4. $log(oil\ price)\ (WTI)$	0.384***	-0.014	-0.204***	1.000		
5. DGI	0.099	0.647***	-0.145**	0.015	1.000	
6. TGI	0.041	0.827***	-0.155**	-0.108*	0.781	1.000

$* p \leq 0.10$, $** p \leq 0.05$, $*** p \leq 0.01$

Table 4b: US VIF test

US VIF	DGI	TGI
$log(size)$	1.95	3.77
$Leverage$	1.76	1.22
$log(oil\ price)\ (WTI)$	1.06	1.09
DGI	1.76	-
TGI	-	3.48
$Mean\ VIF$	1.40	2.12

Table 5a: Europe correlation matrix

Europe correlation	1	2	3	4	5	6
1. ROA	1.000					
2. $log(size)$	0.103	1.000				
3. $Leverage$	0.030	0.124	1.000			
4. $log(oil\ price)\ (Brent)$	0.263**	0.006	-0.210***	1.000		
5. DGI	0.107	0.773***	0.034	0.042	1.000	
6. TGI	0.076	0.836***	0.056	-0.018	0.867***	1.000

* $p \leq 0.10$, ** $p \leq 0.05$, *** $p \leq 0.01$

Table5b: Europe VIF test

Europe VIF	DGI	TGI
$log(size)$	2.58	3.42
$Leveragev$	1.08	1.08
$log(oil\ price)\ (Brent)$	1.06	1.07
DGI	2.54	-
TGI	-	3.37
$Mean\ VIF$	1.66	1.99

As we can see from the correlation matrixes in Tables 4a and 5a, DGI and TGI are correlated with size in both the US and the European data. From previous research, we know that size will increase the green innovation of a company and not vice versa, which means it is not possible to exclude the size variable from the analysis (Lin et al., 2019). This can result in multicollinearity issue and inflate the variance of the coefficients, and consequently make the key variable estimates statistically insignificant. To address this concern, we include a VIF test. The results are reported in Tables 4b and 5b and show no values over 10. This indicates that there is no issue of multicollinearity between these variables. In addition, we include a simple regression model containing only the green innovation scores in the results. Thus, we will be able to observe how the significance levels of the estimated coefficients change between the models and see if the correlation affects any of the results.

4. Methodology and models

4.1 Methodology

When analyzing panel data, observations cannot be assumed to be distributed independently across time. In this case, time-invariant unobserved factors such as age, country of residence, or company culture can be correlated with the independent variables included in the model (Coad et al., 2013; Stinchcombe, 1965). Therefore, if the model has some time-invariant component where $x_{it} = x_i$ for all t, we will have a problem of endogeneity if it is not controlled for. Using a fixed effects model will allow regressors to be endogenous as long as they are only correlated with the time-invariant part of the error-term α_i, where the error $u_{it} = \alpha_i + \varepsilon_{it}$. As we are not interested in the time constant factors, there is no need to control for them individually as long as they are accounted for in the model. When using fixed effects estimation, mean-differencing is used to remove the fixed effects α_i from the parameters in the model:

$y_{it} - \bar{y}_i = (x_{it} - \bar{x}_i)\beta + (\varepsilon_{it} - \bar{\varepsilon}_i)$ where $\bar{x}_i = T_i^{-1} \sum_{t=1}^{T_i} x_{it}$

As the fixed effects are removed, we can estimate consistent coefficients even if $Cov(\alpha_i, x_{it}) \neq 0$.

Based on our hypotheses, the observations from theory and previous literature, we have derived the following function of variables:

$$ROA = f(company\ size, leverage\ ratio, oil\ price, 2014/2015\ oil\ crisis\ dummy,$$
$$green\ innovation, green\ innovation^2, green\ innovation \times oil\ price)$$

To see if the regressors in our model are uncorrelated with the error-term u_{it}, we use the Sargan-Hansen test of overidentifying restrictions, which shows the fixed effects (FE) method is preferred to the random effects (RE) method. Moreover, we compared the estimated results of RE and panel OLS, with the estimated results of FE. The RE estimations for both US and European data resulted in the same outputs as panel OLS, which means the RE estimates are degenerate and there is no difference between the two methods. Comparing the estimations from panel OLS with FE, we find changes in sign and significance level. This indicates that we need to control for the time-invariant component of the error α_i in the model. Thus, the estimations from the fixed effects method is used to avoid a biased result.

In order to confirm the reliability of the results, we perform robustness checks of fixed effects estimations with profit margin and return on equity as the dependent variables, as well as a panel OLS estimation with ROA. The estimated results are listed in the Appendix.

4.2 Models

To explore the hypotheses, we estimate six models. All models are estimated twice for each region. First, with the variable for DGI, then with the variable for TGI. In all models, i denotes the individual companies and t denotes the time. The variable a_i is the fixed effect and δ_t represents the year dummies. The dependent variable $ROA_{i,t}$ is the companies' annual profitability ratio. The key variables $DGI_{i,t-1}$ and $TGI_{i,t-1}$ are introduced with a one-year lag and represent the disruptive green innovation score and total green innovation score respectively. In the introduced models, $\text{size}_{i,t-1}$ is the lagged company size. $LVR_{i,t-1}$ denotes the lagged company leverage ratio. $oil_{i,t}$ is the oil price, reported as WTI for the US and $Brent$ for Europe, in all models. Y14/15_t is a dummy variable for the 2014/2015 oil crisis, which takes the value of 1 in the years 2014 and 2015, and 0 otherwise.

Model 1

Model 1 is the base model containing only the control variables:

$$ROA_{it} = \alpha_0 + \delta_t + \alpha_1 \log(size)_{i,t-1} + \alpha_2 LVR_{i,t-1} + \alpha_3 \log(oil)_{i,t} + \alpha_4 \text{Y14/15}_\text{t} + a_i + \varepsilon_{i,t} \tag{1}$$

This is estimated to have a better indication of how much impact the key variables have on the dependent variable. We observe this by seeing how the coefficients of the control variables change when including the variables for green innovation in the later models. Including the base model is also a good way to observe if there are any multicollinearity issues in the sample.

Model 2

This model is a simple regression containing only one of the green innovation variables in each estimation:

$$ROA_{it} = \alpha_0 + \delta_t + \alpha_1 DGI_{i,t-1}/TGI_{i,t-1} + a_i + \varepsilon_{i,t} \qquad (2)$$

As the correlation matrixes indicated a high correlation between both of the green innovation variables and company size, model 2 is included to see if the correlations affect any of the results in models 3 to 6. This is performed to see if the significance level of the key variables changes when introducing the control variables. Thus, the coefficient estimations from this model will not be interpreted in the results.

Model 3

In Model 3, the key variables are introduced to measure the linear impact of green innovation on the financial performance of oil and gas companies:

$$ROA_{it} = \alpha_0 + \delta_t + \alpha_1 \log(size)_{i,t-1} + \alpha_2 LVR_{i,t-1} + \alpha_3 \log(oil)_{i,t} + \alpha_4 \mathrm{Y14/15_t} + \alpha_5 DGI_{i,t-1}/TGI_{i,t-1} + a_i + \varepsilon_{i,t} \qquad (3)$$

We have two different estimations of the model with two different key variables. Disruptive green innovation score (DGI) measures the impact of innovation, which introduces new market opportunities through new technologies, processes, or products, often characterized as disruptive innovation. Total green innovation score (TGI) includes measures for emissions and resource use in addition to the disruptive green innovation score and represents the total green innovation efforts (sustained and disruptive) in a company.

Model 4

This includes the quadratic term of the key variables:

$$ROA_{it} = \alpha_0 + \delta_t + \alpha_1 \log(size)_{i,t-1} + \alpha_2 LVR_{i,t-1} + \alpha_3 \log(oil)_{i,t} + \alpha_4 \mathrm{Y14/15_t} + \alpha_5 DGI_{i,t-1}/TGI_{i,t-1} + \alpha_6 DGI^2_{i,t-1}/TGI^2_{i,t-1} + a_i + \varepsilon_{i,t}$$

(4)

Model 4 lets us explore if there is a curvilinear relationship between green innovation and the financial performance of oil and gas companies. According to previous literature, we expect the relationship to have an inverse U-shape where the additional effect on financial performance will become negative after reaching the turning point (Uotila et al., 2009; Belderbos et al., 2010).

Model 5

To investigate if there is a moderating effect of oil price on the relationship between green innovation and companies' financial performance, the interaction term of the two variables is introduced in Model 5:

$$ROA_{it} = \alpha_0 + \delta_t + \alpha_1 \log(size)_{i,t-1} + \alpha_2 LVR_{i,t-1} + \alpha_3 \log(oil)_{i,t} + \alpha_4 \mathrm{Y14/15_t} + \alpha_5 DGI_{i,t-1}/TGI_{i,t-1} + \alpha_6 DGI_{i,t-1}/TGI_{i,t-1} \times \log(oil)_{i,t} + a_i + \varepsilon_{i,t} \quad (5)$$

The moderating effect is expected to have a negative sign as a higher oil price reduces the incentive to invest in alternative technology and operating methods. We believe that the effect is especially strong for DGI, as investments in costly disruptive innovation are usually not a priority for companies when it has a high alternative cost. In addition to this, companies will most likely invest in sustained innovation and reduction of emissions and resource use regardless of oil price (Perrons, 2014).

Model 6

In this model, we include all variables used in the previous models:

$$ROA_{it} = \alpha_0 + \delta_t + \alpha_1 \log(size)_{i,t-1} + \alpha_2 LVR_{i,t-1} + \alpha_3 \log(oil)_{i,t} + \alpha_4 \mathrm{Y14/15_t} + \alpha_5 DGI_{i,t-1}/TGI_{i,t-1} + \alpha_6 DGI^2_{i,t-1}/TGI^2_{i,t-1} + \alpha_7 DGI_{i,t-1}/TGI_{i,t-1} \times \log(oil)_{i,t} + a_i + \varepsilon_{i,t} \quad (6)$$

This model is included as a robustness check, to validate that the results in model 1 to 5 still holds.

To account for the presence of heteroskedasticity, robust standard errors are often used. When using robust standard errors, the values of all test statistics reported in the output are valid regardless of serial correlation or heteroskedasticity issues. This is especially important when operating with panel data as standard errors for one time period is most likely not independent of the previous periods. We are using cluster-robust standard errors in the estimation, under the assumption that the errors are independent across individuals, but not over time.

5. Results

5.1 Estimation results for the US oil and gas companies

Table 6 reports the results for the fixed effects estimations of the US data sample, using ROA as the dependent variable. Model 3 highlights the linear effect of the green innovation scores on company financial performance. Models 4 to 6 show the curvilinear relationships of the key variables and the moderating effect of oil price on the relationship between green innovation and financial performance. From the results, we see that all models, except for model 2, are overall statistically significant at the 1% level and there are several significant estimated coefficients. We also find evidence for an effect of DGI and TGI on companies' financial performance. The R^2 within value is higher in the models including TGI than those including DGI. Therefore, the amount of variation in the dependent variable ROA within the companies is better explained by the models including both sustained and disruptive innovation within the categories of green innovation, emissions and resource use, as opposed to those including only the measure for the disruptive green innovation score. For the R^2 between value, which captures variation between individuals, there is an even larger difference in favor of the TGI. Overall, we see that the estimations including TGI better explains the variation in the dependent variable both within and between the companies.

Table 6: US Estimation Results – Fixed Effects

Dependent variable ROA	Model 1 Controls	Model 2 DGI	Model 2 TGI	Model 3 DGI	Model 3 TGI	Model 4 DGI	Model 4 TGI	Model 5 DGI	Model 5 TGI	Model 6 DGI	Model 6 TGI
$\log(size)$	-6.196* (3.391)			-7.743** (3.315)	-9.318** (3.624)	-7.394** (3.317)	-9.436** (3.522)	-7.661** (3.280)	-9.292** (3.496)	-7.007** (3.253)	-9.335** (3.408)
LVR	.075*** (0.020)			.071*** (.019)	.661*** (.020)	.071*** (.019)	.065*** (.019)	.702*** (.019)	.066*** (.019)	.073*** (.019)	.065*** (.018)
$\log(oil)\ (WTI)$	21.255*** (2.930)			21.077*** (2.972)	23.441*** (3.457)	21.574*** (2.968)	24.784*** (3.893)	23.807*** (6.754)	24.104** (8.875)	29.012*** (8.858)	27.477** (10.215)
$Y14/15$	-8.448*** (1.764)			-8.031*** (1.740)	-7.435*** (1.829)	-7.882*** (1.753)	-7.466*** (1.831)	-8.043*** (1.737)	-7.434*** (1.831)	-7.840*** (1.710)	-7.464*** (1.827)
DGI		.081 (.067)		.097* (.057)		1.113 (.658)		.342 (.453)		2.260 (1.570)	
DGI^2						-.008 (.005)				-.012 (.008)	
$DGI \times \log(oil)$								-.056 (.103)		-.148 (.155)	
TGI			-.072 (.084)		.310*** (.094)		.866*** (.304)		.365 (.642)		1.107 (.866)
TGI^2							-.005** (.002)				-.006** (.003)
$TGI \times \log(oil)$									-.012 (.133)		-.049 (.146)
$Constant$	11.269 (50.817)	-2.532 (3.231)	5.005 (4.272)	33.013 (47.352)	37.749 (48.521)	-2.078 (55.246)	22.235 (45.394)	19.733 (44.452)	34.343 (42.530)	-54.324 (72.337)	8.014 (43.310)
n	243	242	242	242	242	242	242	242	242	242	242
N	27	27	27	27	27	27	27	27	27	27	27
F	24.57***	1.44	0.73	18.45***	21.38***	17.52***	16.91***	15.82***	17.79***	16.06***	14.51***
R-sq (within)	0.352	0.002	0.001	0.362	0.378	0.365	0.385	0.362	0.378	0.368	0.386
R-sq (between)	0.311	0.122	0.046	0.281	0.420	0.290	0.464	0.281	0.422	0.296	0.474
R-sq (overall)	0.079	0.010	0.002	0.076	0.104	0.076	0.082	0.079	0.105	0.082	0.084
Joint sig F-test						2.72*	5.83***	1.58	6.44***	1.84	4.58**

*Robust standard errors in parenthesis. * $p \leq 0.10$, ** $p \leq 0.05$, *** $p \leq 0.01$*

Model 1 reports the fixed effects regression results with only the control variables included. We see that the coefficients of all variables are statistically significant with varying degrees of significance level and consequently are expected to have effects on the dependent variable ROA. The within R^2 is 0.352, which means that 35.2% of the variation in the dependent variable within the companies is explained by the control variables included in this study. The coefficient for the variable of company size has a negative sign with a value of -6.196 and is significant at the 10% level. This shows that an increase in company size by 1%, is expected to decrease ROA by -0.062 percentage points on average in the consecutive year. The estimation suggests a negative relationship between company size and accounting profits of oil and gas companies, which Bagirov and Mateus (2019) also found in their study. The coefficient for the leverage ratio is significant at the 1% level with a positive coefficient of 0.075. If the leverage ratio is increased by 1 percentage point, the annual profitability ratio ROA is expected to increase by 0.075 percentage point in the following year. There is no consensus in the literature about the effect of the leverage ratio on the companies' financial performance. Our finding of a positive effect is in line with Lin et al. (2019), while it contradicts findings of a negative effect from other studies (see e.g., Bagirov & Mateus, 2019; Weir & McKnight, 2002). Oil price has an estimated coefficient value of 21.255 and it is statistically significant at the 1% level. The coefficient value indicates that when the oil price is increased by 1%, ROA is predicted to increase by 0.213 percentage point. The coefficient for the dummy variable, the 2014 and 2015 oil price crisis, is negative and significant at the 1% level. This shows that on average, annual ROA decreased by 8.448 percentage points during this period, compared to the other periods in the sample. The estimation confirms that the oil price crisis had a major impact on the financial performance of oil and gas companies, which is expected as the oil and gas industry is resource-based (Dayanandan & Donker, 2011). All estimated effects are ceteris paribus.

Looking at the results in Model 2, we can see that both coefficients of the green innovation variables are statistically insignificant in the simple regression estimations in model 2 and then becomes statistically significant in the estimations in model 3. If there was a multicollinearity issue, the effect would be the opposite.

In model 3, the key variables are added. The coefficient of DGI is positive and significant at the 10% level. We find that when DGI increases by one unit, the annual ROA is expected to increase by 0.097 percentage point in the next year. The coefficient of TGI is significant at the

1% level. With a positive coefficient value, we expect that ROA increases by 0.310 percentage point when the TGI increases by one unit in the previous year.

In model 4, we measure the curvilinear effect of the key variables by introducing quadratic terms. Both of the coefficient estimations for the green innovation scores are jointly significant with their quadratic terms at the 10% and 1% levels, respectively. For DGI, there is no significant curvilinear relationship between the variable and ROA. As the estimated coefficient was positive and significant in model 3, the results indicate a positive and linear effect of DGI on ROA. The quadratic term of TGI is significant at the 5% level, and the coefficient sign is negative, which means there is a positive diminishing effect on ROA for the US companies. The turning point is given by $\left|\frac{.866}{2*.005}\right| = 86.6$ and shows that after TGI reaches 86.9, each additional unit will decrease the company's annual financial performance. The inverted U-shape is consistent with findings in previous literature on green innovation's effects on financial performance (see e.g., Bontis et al, 2005; Misani & Pogutz, 2015; Ramanathan, 2018).

In model 5, we measure the moderating effect of oil price on the relationship between green innovation and companies' financial performance. We find that TGI and its interaction term with oil price are jointly significant at the 1% significance level. However, for US companies there are no significant results in both estimations of the model. Thus, there is no moderating effect of the oil price between the key variables and financial performance. The estimation results conclude that the level of company investments in both sustained and disruptive green innovation for US oil and gas companies are independent of the price for oil.

The results in model 6 confirm that the estimation results in models 1 to 5 still holds when introducing all the variables in a single model. The variables including TGI are jointly significant, which is consistent with the findings in models 4 and 5. The coefficient of the quadratic term of TGI is still negative and significant at the 5% level. None of the coefficient estimations of DGI are statistically significant.

In summary, our results suggest a linear and positive effect from the disruptive green innovation on the US oil and gas companies' financial performance. For TGI, we find that the effect on financial performance is curvilinear with an inverse U-shape. The results indicate that when adding measures for sustaining innovation to reduce emissions and increase the effectiveness of resource use, the effect of green innovation goes from linear to curvilinear with a turning point of 86.6. This is consistent with previous literature, which suggests that too much focus on green innovation efforts might negatively affect other operational activities by using too many resources (Wagner, 2005). Looking at the data used in this study, it seems like many US companies have a significant improvement potential through increasing their TGI as the turning point is quite high compared to the US industry mean of 51.128. In conclusion, we accept hypotheses 1 and 2 for US oil and gas companies and conclude that there is an effect of green innovation on the companies' financial performance. This effect is curvilinear and positive at a decreasing rate until it reaches a turning point and becomes negative. In addition to the curvilinear effect, we find that green innovation's effect on financial performance is independent of the global crude oil prices. Thus, hypothesis 3 is rejected for US companies.

5.2 Estimation results for European oil and gas companies

The estimated results for European oil and gas companies are summarized in Table 7. We see that all models are statistically significant at the 1% level, except for the TGI estimation of model 2. The R^2 values are consistent with the US results, where the within variation for estimations on ROA containing TGI is generally higher than the ones containing DGI, except for model 5. In general, the results show several interesting and significant effects from the key variables. As with the US results, all estimated effects are ceteris paribus.

Table 7: Europe Estimation Results – Fixed Effects

Dependent variable ROA	Model 1 Controls	Model 2 DGI	Model 2 TGI	Model 3 DGI	Model 3 TGI	Model 4 DGI	Model 4 TGI	Model 5 DGI	Model 5 TGI	Model 6 DGI	Model 6 TGI
$\log(size)$	.651 (4.275)			.601 (4.312)	.567 (4.105)	.607 (4.325)	1.563 (4.060)	.417 (4.000)	.400 (4.092)	.424 (4.018)	1.399 (4.079)
LVR	.028 (.049)			.028 (.050)	.027 (.052)	.032 (.049)	.028 (.051)	.049 (.046)	.041 (.048)	.053 (.045)	.041 (.048)
$\log(oil)\ (WTI)$	6.981*** (1.735)			7.024*** (1.760)	7.042*** (1.826)	7.068 *** (1.76)	7.935*** (1.954)	14.231*** (4.777)	14.303 (8.682)	14.184*** (4.776)	14.455** (5.488)
$Y14/15$	-9.262*** (2.458)			-9.276*** (2.461)	-9.277*** (2.451)	-9.387*** (2.504)	-9.205*** (2.293)	-9.161*** (2.411)	-9.099*** (2.562)	-9.261*** (2.458)	-9.046*** (2.337)
DGI		.055*** (.018)		-.013 (.019)		.074 (.072)		.457* (.245)		.528** (.249)	
DGI^2						-.001 (.001)				-0.001 (.001)	
$DGI \times \log(oil)$								-.114* (.060)		-.112* (.060)	
TGI			.028 (.702)		.063 (.139)		-.956** (.408)		.494 (.520)		-.553 (.659)
TGI^2							.009** (.004)				.009* (.004)
$TGI \times \log(oil)$									-.102 (.106)		-.092 (.072)
$Constant$	-37.189 (70.938)	-.723 (1.076)	.702 (11.341)	-35.78 (71.760)	-40.372 (74.062)	-36.688 (72.277)	-36.738 (67.759)	-63.202 (70.746)	-68.81 (73.418)	-63.683 (70.990)	-62.377 (62.620)
n	153	153	153	153	153	153	153	153	153	153	153
N	17	17	17	17	17	17	17	17	17	17	17
F	9.5***	9.85***	0.03	7.98***	7.86***	6.93***	8.29***	8.09***	7.94***	7.29***	8.27***
R-sq (within)	0.226	0.003	0.000	0.227	0.228	0.228	0.256	0.236	0.233	0.237	0.260
R-sq (between)	0.217	0.142	0.086	0.205	0.161	0.000	0.254	0.031	0.153	0.029	0.260
R-sq (overall)	0.225	0.012	0.006	0.225	0.210	0.203	0.132	0.220	0.221	0.185	0.143
Joint sig F-test						0.73	2.79*	1.77	0.47	1.75	3.26**

Robust standard errors in parenthesis. * $p \leq 0.10$, ** $p \leq 0.05$, *** $p \leq 0.01$

Model 1 includes only the control variables. We see that the coefficients for company size and the leverage ratio are not statistically significant, which indicates these two variables do not affect the financial performance of European oil and gas companies. This is different from both the estimations found in the US data and from previous studies where these effects have been confirmed several times, even if there has been little consensus around the sign of the coefficients (see e.g., Bagirov & Mateus, 2019; Lin et al., 2019). However, the two control variables involving the oil price are both significant. The coefficient of oil price is significant at the 1% level and has a positive coefficient of 6.981. This means that when Brent crude oil price increases by 1%, ROA is expected to increase by 0.070 percentage point on average in the same year. The coefficient of the dummy variable of the 2014 and 2015 oil crisis is significant at the 1% level and has a value of -9.262. Thus, European oil and gas companies' ROA was on average 9.262 percentage points lower than normal during the oil crisis. The result is consistent with previous studies where shocks on the oil price are found to have a significant impact on company financial performance in the European oil and gas industry (Bagirov & Mateus, 2019).

In model 2 including DGI, we see that the estimation result of the coefficient of DGI is positive and significant at the 1% level. When including the control variables in model 3, the coefficient of DGI becomes insignificant. However, it becomes again significant in models 5 and 6 when including the interaction term with oil price. For the model including TGI, we see that the coefficient of TGI is insignificant in model 2 and becomes significant in the estimations in model 4, which adds the quadratic term of TGI.

Model 3 adds the key variables of the green innovation scores. The estimation result shows that the level of the previous year's DGI has a negative effect on financial performance, while TGI has a positive effect. However, both estimated coefficients are insignificant, which implies that green innovation has no linear effect on European oil and gas companies' financial performance.

Model 4 adds the quadratic term to explore if there is any proof of a curvilinear effect. The estimation result shows that there is no significant curvilinear relationship between DGI and

ROA. However, the coefficient of TGI is negative and significant at the 5% level, while the coefficient of its quadratic term is positive and significant at the 5% level. The two variables are jointly significant at the 10% level. The result shows that there is a curvilinear U-shaped relationship between total green innovation and ROA, with a turning point of $\left|\frac{.956}{2*.009}\right| = 53.11$. In other words, TGI has a negative increasing effect on ROA. This means that when TGI is lower than 53.11, the effect of one additional unit of TGI on financial performance is negative but when the score becomes higher than 53.11, the effect turns positive. The U-shaped relationship shows that European oil and gas companies should either not invest in green innovation at all or invest sufficient funds in green innovation practices to gain financial benefits.

Model 5 includes an interaction term of oil price and the key variables. The result shows that the coefficient of DGI has a positive effect on ROA, which is 0.457 at the 10% significance level. The coefficient of interaction term of DGI and oil price is -0.114 and significant at the 10% level. However, the joint significant test of these two variables is insignificant. The result indicates that there exists a weak moderating effect of oil price on the relationship between the disruptive green innovation and the oil and gas companies' financial performance, where an additional percentage increase in oil price will lower the positive effect of the previous year's DGI on ROA. The coefficients for TGI and its interaction term have the same sign as DGI. However, the estimates are not statistically significant, and we cannot confirm a moderating relationship between the oil price and the European oil and gas companies' total green innovation efforts.

Model 6 acts as a robustness check and it adds all the independent variables used in the previous five models, including both quadratic terms of the green innovation variables and the interaction term of oil price and green innovation. For DGI, the results are consistent with previous results from model 5. The coefficient of the interaction term is -0.112 and significant at the 10% level. The estimates for TGI show that the coefficient of the quadratic term is positive with a magnitude of 0.009 and is significant at the 10% level. This result is also consistent with what we previously obtained from Model 4. The joint significant test of the three independent variables shows that TGI, the quadratic term of TGI, and the interaction term of TGI and Brent crude oil price, are jointly significant at the 5% significance level.

For the European companies, we do not find any significant linear effect of green innovation on the oil and gas companies' financial performance. This includes both sustained and disruptive innovation efforts. The results show a U-shaped curvilinear relationship between TGI and ROA. These findings have previously been identified by Trumpp and Guenther (2017), which argue companies must make a minimum level of commitment to green innovation before the positive effects on financial performance start to show. Therefore, we confirm hypotheses 1 and 2, as we find that there is an effect of green innovation on the financial performance of European oil and gas companies and that the relationship is curvilinear with a negative increasing effect. We also find some evidence for a moderating effect of oil price on the relationship between disruptive green innovation and financial performance for European companies. The estimation results suggest that when oil price increases, the effect of disruptive green innovation on financial performance decreases. As previous literature suggests, high oil prices might dampen the fall when investing in disruptive innovation projects, making companies more likely to take risky investment decisions (Rassenfoss & Henni, 2015). The results show no significant interaction effect between TGI and oil price. This makes sense as companies' investment activities in continuous improvements of products and processes, is a means to survive in the short term and more based on day to day operations. Thus, we also confirm hypothesis 3 for European companies, which conclude that there is a moderating effect of oil price on the relationship between green innovation and financial performance.

5.3 Robustness check

To see if the hypotheses testing results still hold when using alternative measures of financial performance or changing the estimation method, we have performed several robustness checks. The results from using alternative financial performance measures are reported in the Appendix, Tables 8, 9, 11, and 12. The results from the panel OLS estimations on the dependent variable

ROA are reported in the Appendix, Tables 10 and 13.

For the US results, several significant findings in the original models become insignificant when introducing new dependent variables. Performing two additional fixed effects analyses with dependent variables of profit margin (PM) (Table 8) and return on equity (ROE) (Table 9), we find little significant results confirming hypotheses 1 and 2. In the analysis using panel OLS with dependent variable ROA (Table 10), there is no evidence of a linear effect from the key variables and a weakly significant result of a curvilinear effect from DGI (though not jointly significant). The results confirmed by all four models suggest that hypothesis 3 on the moderating effect of oil price is rejected for US companies.

In the robustness checks for European companies, the results are more similar to the original fixed effects analysis. In the analysis using PM as the dependent variable (Table 11), there is evidence of a linear effect of DGI, as well as a significant moderating effect of oil price on both key variables. However, the weak and significant curvilinear result found in the analysis using ROA has become insignificant. In the fixed effects estimation using ROE (Table 12), there are no significant findings from the key variables, while the results for panel OLS with ROA (Table 13) show similar results as the main analysis.

6. Discussion

6.1 Green innovations effect on the financial performance

6.1.1 US

From the US estimations, we find that there is a curvilinear effect from green innovation on financial performance, where the effect is diminishing positive with an inverse U-shape. Comparing this result to the resource-based view, the theory suggests that US companies utilize their unique capabilities efficiently and generate a positive relationship. The positive effect is expected to diminish when the incremental investment eventually starts to increase economic costs, changing the trajectory of the cost-benefit relationship. This suggests that for US companies, green innovation is more proactive and treated as an opportunity to improve financial performance, rather than a cost imposed by governmental regulations. Previous studies have also shown that when companies are free to innovate on their own terms, the financial outcome is often better (Noci & Verganti, 1999; Bigliardi et al., 2012). This effect is substantiated by the fact that investors and shareholders are becoming increasingly more environmentally conscious (Shojaeddini et al., 2019). When companies demonstrate a willingness to invest in green innovation and have the capabilities to turn the investment into positive financial gains, it is a win-win situation for all parties. We also find evidence that disruptive green innovation has a positive and linear effect on US oil and gas companies' financial performance. Putting efforts into developing new and green products and processes will assure the long-term survival of a company by maintaining competitiveness when markets change. As we see a shift towards higher awareness of climate change, there are good opportunities for the US oil and gas companies to utilize their disruptive innovations to improve their financial performance through the mechanisms of differentiation, cost reduction, and green image.

6.1.2 Europe

The results indicate that green innovation has a curvilinear effect on European oil and gas companies' financial performance, in which the effect is increasing negative with a U-shape. This means the financial performance of oil and gas companies will decline at an early stage of green innovation and then turn positive when the green innovation achieves a certain level (turning point). There can be several reasons for this phenomenon. First, innovation can result in a negative effect on the financial performance of the company due to the high risk during the innovation process (de Oliveira et al., 2018). If the innovation fails, companies get nothing from the investment but increased operating costs and lower profit. Secondly, it is time-consuming to recoup investments in green innovation. For new product innovations, the consumers and the market may not be prepared to accept them at an early stage. For process innovation, it is costly and time-consuming to implement and is barely noticeable by the consumers (Li et al., 2017). Third, the positive effect on financial performance can be hard to identify if there is no sufficient environmental policy and financial support (Rennings, 2000). Forth, European counties comply with much stricter environmental regulations than the US (Bakker & Francioni, 2014). As the European companies pay more attention to compliance with the regulations than to take initiative in green innovation practices, there would be fewer first-mover advantages (Aguilera-Caracuel & Ortiz-de-Mandojana, 2013). Responsive and regulation-driven innovations have been proved to be time-consuming and inefficient in previous studies (Noci & Verganti, 1999; Bigliardi, 2012). According to Aguilera-Caracuel and Ortiz-de-Mandojana (2013), the stringency of environmental regulations has a negative effect on the relationship between green innovation and companies' financial performance. Finally, it also indicates that the European region does not have effective channels and market mechanisms for green innovation to produce a profit. Thus, only when achieving a certain level of economic scale, can the green innovation promote the companies' financial performance.

6.2 Moderating effect of oil price

6.2.1 US

There is no evidence from our results for a moderating effect of oil price on the effect of green innovation on US oil and gas companies' financial performance. We identify two mechanisms, which might explain the result. Firstly, research shows that companies operating in the US have a much higher concentration of R&D spending than their European counterparts, regardless of operating revenue and volatility in the business cycle. The top US companies have increased their share of R&D expenditure in the last 10 years, while the share invested by European companies has decreased (Hernández et al., 2019). This suggests that the culture and willingness for investing in innovation are higher in US businesses, which traditionally have shown to have a big impact on both the rate and the success of innovation efforts (Jamrog et al., 2006). As pointed out by Bakker and Francioni (2014), the US complies with less strict environmental regulations than Europe, thus the US oil and gas companies take more initiative to invest in green innovation. They implement the innovation investment out of cost-benefit analysis and long-term sustainability, rather than the requirement to meet the regulations. Secondly, the US is self-sufficient in the supply of oil and gas, which makes them less sensitive to fluctuation in the oil price.

6.2.2 Europe

Brent crude oil price has a negative moderating effect on the relationship between disruptive green innovation and financial performance. It indicates that there is a detrimental effect from higher oil prices on the financial performance improvement caused by green innovation. It implies that when the oil price is high, the oil and gas companies should focus on their conventional business rather than dispatch the resources on green innovation. The high oil price increases the cost for the companies from the demand side, and the substitute effect motivates them to increase energy efficiency or initiate new energy innovation. However, oil and gas companies operate on the supply side. According to the microeconomic short-term demand and supply theory, a higher price causes the supply curve to move to the right and induces more production of oil and gas as long as it is profitable to do so. High oil price suggests that the supply is in shortage and the demand from the consumer side is strong. As the resources are limited, without strict environmental regulations there is no reason for oil and gas companies to disregard such demand and make high-risk investments in disruptive innovation. On the other hand, when the oil price is low, innovation, especially disruptive innovation, becomes important since the oil and gas companies need to explore new market opportunities, seek new profit sources, and pursue business sustainability.

6.3 Comparison of US and Europe results

As the biggest economic powers in the world, the US and the European regions play an important role in energy technology development and environmental protection. They share common targets, at the same time, there are also important divergences between them.

First of all, the US and the European countries have different capabilities in oil and gas self-sufficiency. With the development of new technology of oil and gas extraction, the US has achieved self-sufficiency in oil and gas. The US became an oil and gas exporting country only in recent years while it was one of the main importing regions not long ago. Comparatively, European countries have a high level of dependency on oil and gas imports. It has a positive effect on the European countries and companies to invest more in green innovation, especially the investment in alternative energy to reduce the dependency on oil and gas imports (Bousso & Nasralla, 2020). As pointed out by Bousso and Nasralla (2020), the European top five oil and gas producers BP, Shell, Total, Eni and Equinor have cut investments in oil and gas projects but maintain or even increase the share of investment in renewable energies and low-carbon business, while the US oil and gas producers, such as Exxon and Chevron, are persisting their enthusiasm in the traditional oil and gas business.

Secondly, the US and the European countries have different willingness and attitudes toward pursuing environmental performance and company financial performance. As Bakker and Francioni (2014) pointed out, the US has concerns that complying with emission reduction regulations could hurt the competitiveness of the industries. To avoid the commitment to international environmental regulation, the US set up its environmental regulation system at the national level. The US emphasizes more on the cost-benefit analysis and the companies' financial performance. On the contrary, European countries have environmental protection as a priority. The European Union has established increasing regulations on environment protection and greenhouse gas emission reductions, and such policies are even beyond the requirements in the Kyoto Protocol (Bakker & Francioni, 2014). Thus, the US is more profit-driven and Europe is more regulation- and motivation-driven with regards to green innovations. Europe committed itself through multilateral international agreements, which means the regulations in Europe are much stricter than the ones in the US. Therefore, it is not strange that green innovation shows a better effect on financial performance in the US oil and gas companies. As pointed out by Aguilera-Caracuel and Ortiz-de-Mandojana (2013), stricter environmental regulations have negative effects on the relationship between green innovation and companies' financial performance.

7. Conclusion

7.1 Summary of findings

We find evidence that green innovation has a curvilinear effect on US oil and gas companies' financial performance with a diminishing positive effect. This means that at low levels of green innovation, more green innovation increases companies' financial performance but at a decreasing rate. This effect persists until a certain level is reached and the relationship becomes negative. We suspect the positive effect is partly attributed to the region's innovation culture as well as the lack of restricting governmental regulations and not the characteristics of the industry. This is strengthened by the fact that we do not find a moderating effect of oil price on this relationship, which indicates that the traditional revenue streams of US oil and gas companies do not impact the success of new and green innovation investments. For European oil and gas companies, we identify a U-shaped curvilinear relationship between green innovation and financial performance. This means that at low levels of green innovation, it has a negative effect on European companies' financial performance. At high levels of green innovation (after the turning point), the effect becomes positive. We believe this relationship is due to the risky nature of innovation, where the implementations are often costly and time-consuming. In addition, we see that governmental regulation around green product and process innovations are more prevalent in Europe compared to the US. These results in green innovation investments being more of a response to regulations, rather than being a potential benefit for increased future revenue streams. We also find that there is a negative moderating effect of Brent crude oil price on the relationship between disruptive green innovation and the financial performance of European companies. When the oil price is high, allocating resources into disruptive innovation has a higher opportunity cost than to continue the conventional oil and gas production. In summary, there is a distinct difference between the two regions in terms of the effect of green innovation on financial performance. We see that European companies are more willing to invest in green innovation, however, the effects of the investments in terms of financial benefits are questionable. US companies invest less in green innovation, but more efficiently, which in turn has positive effects on their financial performance. We can only speculate if European companies would invest more efficiently in regard to financial benefits under less governmental regulations, or if they would resort to decreasing their overall investments into green innovation.

7.2 Limitations

The main limitation of this study was the data available for the different regions. Due to the lack of complete data in the DataStream database, we were only able to identify a limited amount of companies that fulfilled the sample selection criteria. We believe this can be a result of ESG data being a relatively new concept. Thus, data from smaller companies with a limited amount of published information are hard to collect compared to data from the big international oil companies. The consequence might be biased results, which are not representative of the larger oil and gas industry. However, we still believe using third-party panel data is an advantage to our study despite the lack of observations, as most other studies use survey data where the responses might not be objective.

7.3 Suggestions for future research

As the world is becoming more conscious about the challenges we face with global warming, it is increasingly important to explore how businesses can innovate their operations in a sustainable and environmentally friendly way. As a suggestion for future research, we think it would be interesting to repeat the study for oil and gas companies in other regions. Particularly in Africa and the Middle East, which have historically been major exporters of oil and gas and highly dependent on the crude oil price (BP, 2019). We would also like to see the result of a similar study in other highly polluting industries in the US and in Europe. This is to see how the results in other industries are different compared to our findings from the oil and gas industry and if there are any similar characteristics. We also suggest taking a closer look at the European region and how the different governmental regulations impact the effect of green innovation on financial performance. Since the International Association of oil and gas producers (IOGP) works closely with the European Union in developing industry-wide best practices, it is important to identify which regulations create opportunities and which create unnecessary costs for the companies in the industry (IOGP, 2020). Lastly, it is interesting to see if the results hold in a similar study where data is collected from an alternative source with a different definition of green innovation.

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Appendix

Robustness check overview

- *Table 8: US robustness check - Fixed effects with dependent variable Profit Margin*
- *Table 9: US robustness check - Fixed effects with dependent variable ROE*
- *Table 10: US robustness check - Pooled OLS with dependent variable ROA*
- *Table 11: Europe robustness check - Fixed effects with dependent variable Profit Margin*
- *Table 12: Europe robustness check - Fixed effects with dependent variable ROE*
- *Table 13: Europe robustness check - Pooled OLS with dependent variable ROA*

Table 8: US robustness check - Fixed effects with dependent variable Profit Margin

Dependent variable	Model 1	Model 2		Model 3		Model 4		Model 5		Model 6	
PM	Controls	DGI	TGI	DGI	TGI	DGI	TGI	DGI	TGI	DGI	TGI
$log\ (size)$	-13.370*** (3.522)			-14.270*** (3.890)	-15.140*** (3.847)	-14.320*** (3.991)	-15.300*** (3.829)	-13.650*** (3.863)	-14.740*** (4.015)	-12.960*** (3.825)	-14.810*** (3.952)
LVR	.054** (.022)			.052** (.021)	.049** (.021)	.052** (.021)	.047** (.020)	.057** (.023)	.052** (.021)	.059** (.024)	.051** (.020)
$log\ (oil)\ (WTI)$	42.800*** (7.857)			42.680*** (7.884)	44.100*** (7.646)	42.600*** (7.913)	45.940*** (9.320)	63.260*** (18.410)	54.070*** (13.080)	68.750*** (20.670)	59.190*** (12.900)
$Y14/15$	-9.302 (7.470)			-9.042 (7.478)	-8.717 (7.617)	-9.065 (7.522)	-8.761 (7.642)	-9.132 (7.493)	-8.704 (7.684)	-8.918 (7.458)	-8.750 (7.705)
DGI		.040 (.135)		.074 (.105)		-.085 (1.239)		1.921 (1.222)		3.943 (2.409)	
DGI^2						.001 (.010)				-.013 (.011)	
$DGI \times log\ (oil)$								-.423 (.275)		-.520 (.320)	
TGI			-.571** (.246)		.184 (.156)		.944 (.740)		1.004 (1.472)		2.131* (1.233)
TGI^2							-.007 (.007)				-.008 (.006)
$TGI \times log\ (oil)$									-.184 (.315)		-.239 (0.298)
$Constant$	68.09 (56.66)	28.73*** (6.48)	59.82*** (12.57)	79.96 (60.50)	82.34 (60.98)	85.43 (79.15)	61.12 (66.06)	-20.15 (88.06)	31.11 (99.63)	-98.24 (124.00)	-8.864 (91.94)
n	243	242	242	242	242	242	242	242	242	242	242
R-sq within	0.246	0	0.018	0.246	0.247	0.246	0.25	0.252	0.248	0.254	0.252
F	18.47***	0.088	5.385**	14.86***	15.13***	12.65***	13.28***	12.11***	16.21***	10.53***	13.43***
Joint sig F- test						0.25	1.59	1.28	0.73	1.05	1.74

*Robust standard errors in parenthesis. * $p \leq 0.10$, ** $p \leq 0.05$, *** $p \leq 0.01$*

Table 9: US robustness check - Fixed effects with dependent variable ROE

Dependent variable	Model 1	Model 2		Model 3		Model 4		Model 5		Model 6	
ROE	Controls	DGI	TGI	DGI	TGI	DGI	TGI	DGI	TGI	DGI	TGI
$log\ (size)$	-52.530 (42.940)			-59.300 (45.100)	-65.870 (47.660)	-59.080 (46.310)	-65.960 (47.450)	-56.020 (44.170)	-57.670 (46.300)	-52.320 (43.970)	-57.520 (45.930)
LVR	1.466 (1.098)			1.411 (1.099)	1.334 (1.101)	1.413 (1.093)	1.322 (1.120)	1.437 (1.098)	1.299 (0.990)	1.470 (1.090)	1.260 (.996)
$log\ (oil)\ (WTI)$	125.50* (69.550)			123.60* (69.840)	132.90* (75.620)	124.00* (68.420)	134.60* (74.250)	206.50 (138.00)	295.80 (238.40)	234.70 (145.10)	309.10 (244.80)
$Y14/15$	-57.180 (39.940)			-55.420 (39.51)	-53.280 (38.790)	-55.330 (40.010)	-53.380 (38.840)	-55.810 (39.51)	-53.250 (37.590)	-54.720 (32.280)	-53.540 (37.870)
DGI		.209 (.199)		.544 (.455)		1.185 (5.102)		7.850 (6.369)		17.980 (11.570)	
DGI^2						-.005 (.041)				-.063 (.049)	
$DGI \times log\ (oil)$								-1.677 (1.410)		-2.167 (1.578)	
TGI			-1.043 (.832)		1.306 (.923)		2.091 (1.836)		14.490 (14.320)		17.470 (15.64)
TGI^2							-.008 (.018)				-.022 (.019)
$TGI \times log\ (oil)$									-2.956 (3.028)		-3.104 (3.096)
$Constant$	279.00 (439.00)	-24.49** (9.64)	39.53 (43.04)	374.90 (459.00)	405.20 (458.60)	352.70 (584.40)	383.20 (476.50)	-40.83 (314.80)	-456.70 (527.20)	-439.80 (460.50)	-564.90 (569.50)
n	231	230	230	230	230	230	230	230	230	230	230
R-sq within	0.074	0	0.002	0.076	0.077	0.076	0.077	0.078	0.086	0.079	0.087
F	1.46	1.099	1.57	1.106	1.049	1.428	0.987	2.676**	1.826	2.218*	1.702
Joint sig F- test						0.74	1.4	0.98	0.8	0.9	0.64

*Robust standard errors in parenthesis. * $p \leq 0.1$, ** $p \leq 0.05$, *** $p \leq 0.01$*

Table 10: US robustness check - Pooled OLS with dependent variable ROA

Dependent variable	Model 1	Model 2		Model 3		Model 4		Model 5		Model 6	
ROA	Controls	DGI	TGI	DGI	TGI	DGI	TGI	DGI	TGI	DGI	TGI
$log\ (size)$	1.173* (.611)			.502 (.875)	.331 (1.037)	.585 (.854)	.239 (1.051)	.498 (.883)	.331 (1.037)	.621 (.858)	.238 (1.054)
LVR	.035*** (.007)			.033*** (.007)	.033*** (.007)	.034*** (.007)	.033*** (.007)	.034*** (.007)	.033*** (.007)	.035*** (.007)	.033*** (.007)
$log\ (oil)\ (WTI)$	19.680*** (2.202)			19.550*** (2.193)	20.020*** (2.258)	19.93*** (2.230)	19.65*** (2.292)	23.35*** (5.374)	20.13*** (6.209)	28.110*** (7.526)	19.210*** (6.500)
$Y14/15$	-11.450*** (2.746)			-11.24*** (2.701)	-11.200*** (2.605)	-11.04*** (2.673)	-11.16*** (2.620)	-11.23*** (2.695)	-11.19*** (2.604)	-10.900*** (2.623)	-11.160*** (2.620)
DGI		.078** (.032)		.063 (.048)		.928* (.488)		.400 (.425)		2.073 (1.298)	
DGI^2						-.007* (.004)				-.010* (.006)	
$DGI \times log\ (oil)$								-.079 (.093)		-.165 (.142)	
TGI			.029 (.037)		.055 (.056)		-.080 (0.161)		.064 (.463)		-.117 (.558)
TGI^2							.001 (.001)				.001 (.001)
$TGI \times log\ (oil)$									-.002 (.103)		.008 (.106)
$Constant$	-100.8*** (15.00)	-2.406 (1.81)	-0.122 (2.08)	-92.22*** (17.40)	-91.18*** (17.58)	-119.0*** (22.18)	-85.03*** (20.40)	-108.5*** (27.99)	-91.66** (34.15)	-166.7*** (52.22)	-83.07** (38.25)
n	243	242	242	242	242	242	242	242	242	242	242
R-sq	0.26	0.01	0.002	0.264	0.262	0.267	0.264	0.265	0.262	0.27	0.264
F	33.3***	5.978**	0.614	25.06***	25.46***	24.98***	20.51***	20.32***	21.18***	20.39***	17.76***
Joint sig F- test						2.03	0.81	0.86	0.51	1.29	0.54

*Robust standard errors in parenthesis. * $p \leq 0.10$, ** $p \leq 0.05$, *** $p \leq 0.01$*

Table 11: Europe robustness check - Fixed effects with dependent variable Profit Margin

Dependent variable	Model 1	Model 2		Model 3		Model 4		Model 5		Model 6	
PM	Controls	DGI	TGI	DGI	TGI	DGI	TGI	DGI	TGI	DGI	TGI
$log\ (size)$	-14.200* (8.000)			-14.790* (8.182)	-14.190* (8.060)	-14.800* (8.211)	-12.830 (7.373)	-13.830* (7.045)	-15.040* (7.554)	-13.850* (7.060)	-13.800* (7.588)
LVR	.164 (.196)			.166 (.199)	.165 (.192)	.165 (.202)	.166 (.191)	.299 (.207)	.294 (.192)	.295 (.208)	.295 (.188)
$log\ (oil)\ (Brent)$	18.420* (8.730)			18.980** (8.789)	18.200** (8.515)	18.960** (8.845)	19.260** (8.867)	65.230*** (21.400)	86.480*** (27.370)	65.28*** (21.490)	86.96*** (25.950)
$Y14/15$	-4.369 (4.035)			-4.550 (4.034)	-4.221 (4.116)	-4.505 (4.065)	-4.25 (3.995)	-4.270 (3.844)	-2.538 (4.333)	-4.147 (3.902)	-2.576 (4.163)
DGI		-.022 (.071)		-.155* (.074)		-.187 (.225)		2.791*** (.934)		2.709** (.928)	
DGI^2						.000 (.003)				.001 (.002)	
$DGI \times log\ (oil)$								-.715*** (.235)		-.717*** (.236)	
TGI			-.244 (.242)		-.151 (.199)		-1.193 (0.858)		3.874*** (1.253)		2.904** (1.301)
TGI^2							.009 (.007)				.008 (.008)
$TGI \times log\ (oil)$									-.9510*** (.304)		-.945*** (.285)
$Constant$	175.20 (105.20)	26.48*** (4.39)	42.100** (16.830)	192.10* (109.60)	186.40 (114.00)	192.50* (110.16)	183.30 (110.20)	-18.76 (81.14)	-93.50 (78.05)	-18.07 (81.08)	-94.39 (81.54)
n	146	146	146	146	146	146	146	146	146	146	146
R-sq within	0.131	0.000	0.007	0.137	0.134	0.137	0.142	0.227	0.228	0.227	0.234
F	2.514*	0.096	1.017	2.228	2.171	1.86	2.424*	2.734*	5.247***	2.554*	4.523***
Joint sig F- test						2.79*	0.97	4.88**	4.91**	3.23*	4.07**

Robust standard errors in parenthesis. * $p \leq 0.10$, ** $p \leq 0.05$, *** $p \leq 0.01$

Table 12: Europe robustness check - Fixed effects with dependent variable ROE

Dependent variable	Model 1	Model 2		Model 3		Model 4		Model 5		Model 6	
ROE	Controls	DGI	TGI	DGI	TGI	DGI	TGI	DGI	TGI	DGI	TGI
$log\ (size)$	-9.151 (7.195)			-9.105 (7.270)	-9.307 (6.854)	-9.063 (7.300)	-8.057 (6.813)	-9.465 (6.855)	-9.624 (6.906)	-9.421 (6.898)	-8.366 (6.895)
LVR	.062 (.148)			.061 (.151)	.080 (.152)	.064 (.149)	.070 (.152)	.095 (.146)	.090 (.142)	.096 (.146)	.079 (.145)
$log\ (oil)\ (Brent)$	16.020*** (3.618)			15.970*** (3.746)	16.230*** (3.814)	15.950*** (3.730)	17.460*** (3.967)	27.420** (10.350)	26.490 (15.770)	27.090** (10.370)	27.000** (11.380)
$Y14/15$	-17.940*** (4.314)			-17.92*** (4.347)	-17.99*** (4.308)	-18.13*** (4.419)	-17.90*** (4.125)	-17.78*** (4.304)	-17.76*** (4.500)	-17.95*** (4.377)	-17.69*** (4.217)
DGI		.209*** (.036)		.012 (.041)		.192 (.165)		.746 (.530)		.868 (.552)	
DGI^2						-.002 (.002)				-.002 (.002)	
$DGI \times log\ (oil)$								-.180 (.134)		-.174 (.134)	
TGI			.169 (.306)		.232 (.220)		-1.149 (0.682)		.838 (.951)		-.569 (1.291)
TGI^2							.012* (.006)				.012 (.007)
$TGI \times log\ (oil)$									-.144 (.196)		-.134 (.149)
$Constant$	87.59 (121.00)	-8.463*** (2.220)	-7.355 (21.25)	86.37 (122.30)	72.60 (117.50)	84.23 (123.10)	79.54 (109.30)	44.37 (116.50)	34.29 (116.30)	43.85 (117.20)	43.75 (105.10)
n	149	149	149	149	149	149	149	149	149	149	149
R-sq within	0.301	0.010	0.004	0.301	0.308	0.302	0.323	0.308	0.311	0.308	0.325
F	9.128***	33.75***	0.307	15.8***	8.258***	27.4***	7.663***	12.57***	8.021***	10.95***	7.034***
Joint sig F- test						1	2.08	1.36	0.56	1.36	2.99*

*Robust standard errors in parenthesis. * $p \le 0.10$, ** $p \le 0.05$, *** $p \le 0.01$*

Table 13: Europe robustness check - Pooled OLS with dependent variable ROA

Dependent variable	Model 1	Model 2		Model 3		Model 4		Model 5		Model 6	
ROA	Controls	DGI	TGI	DGI	TGI	DGI	TGI	DGI	TGI	DGI	TGI
$log\ (size)$	.539 (.340)			.560 (.537)	.675 (.626)	.535 (.601)	.276 (.645)	.638 (.549)	.715 (.636)	.546 (.587)	.315 (.646)
LVR	.023 (.029)			.023 (.029)	.022 (.027)	.023 (.029)	.023 (.026)	.029 (.028)	.026 (.025)	.029 (.029)	.027 (.025)
$log\ (oil)\ (Brent)$	6.927*** (2.040)			6.930*** (1.861)	6.890*** (1.913)	6.943*** (1.866)	7.337*** (1.823)	13.030** (4.502)	13.240 (8.299)	13.420** (4.628)	14.040** (6.229)
$Y14/15$	-9.257*** (2.040)			-9.266*** (2.031)	-9.279*** (2.105)	-9.254*** (2.057)	-9.049*** (1.963)	-9.229*** (2.031)	-9.191*** (2.169)	-9.181*** (2.064)	-8.954*** (1.984)
DGI		.041* (.020)		-.002 (.028)		-.017 (.052)		.425* (.235)		.392 (.228)	
DGI^2						.000 (.001)				.001 (.001)	
$DGI \times log\ (oil)$								-.100* (.055)		-.105* (.057)	
TGI			.039 (.052)		-.017 (.088)		-.552* (.298)		.372 (.508)		-.146 (.552)
TGI^2							.004* (.002)				.004* (.002)
$TGI \times log\ (oil)$									-.091 (.103)		-.096 (.078)
$Constant$	-34.97** (12.06)	0.176 (1.740)	-0.046 (4.090)	-35.19** (13.54)	-35.84*** (10.82)	-34.53** (14.68)	-16.75 (14.32)	-62.68** (24.42)	-63.80 (37.14)	-61.66** (24.49)	-46.08 (34.76)
n	153	153	153	153	153	153	153	153	153	153	153
R-sq	0.226	0.012	0.006	0.226	0.226	0.226	0.249	0.233	0.23	0.234	0.253
F	8.744***	4.278*	0.569	6.962**	6.827***	6.49***	6.58***	7.522***	7.192***	7.296***	6.597***
Joint sig F- test						0.07	2.02	1.66	0.95	1.17	2.61*

*Robust standard errors in parenthesis. * p ≤ 0.10, ** p ≤ 0.05, *** p ≤ 0.01*